NOAA Technical Memorandum NWS SR-193

LIGHTNING FATALITIES, INJURIES AND DAMAGE REPORTS IN THE UNITED STATES FROM 1959-1994

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August 1997

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ABSTRACT

Lightning-related fatality, injury, and damage reports in the US were summarized for 36 years since 1959, based on the NOAA publication *Storm Data*. There were 3239 deaths, 9818 injuries, and 19,814 property-damage reports from lightning during this period. The number of lightning-caused casualty and damage events was less variable from year to year than other weather causes. For this reason, lightning is the most constant and widespread threat to people and property during the thunderstorm season.

By state, Florida led the nation in the actual number of deaths and injuries, while the largest number of damage reports came from Pennsylvania. There were large variations among decades in casualties and damages. When population was taken into account, New Mexico (all decades) and Wyoming (mainly in the 1960s and 1970s) led the nation in death, injury, and casualty rates. High casualty rates tended to be in Florida, the Rocky Mountains, plains, southeast, and New England. The highest rates of population-weighted damage reports were on the plains.

By month, all types of lightning reports in *Storm Data* reached maxima during July. Damage reports were spread more evenly through the year than were casualties. Casualties and damages in northern regions of the US had narrower distributions centered on summer than southern regions.

Within the day, two-thirds of the casualties occurred between noon and 6 p.m. There were relatively frequent damage reports during the night in the plains and midwest states. In winter, the afternoon peak disappeared for damage reports and was weak for casualties. Casualties were most frequent on Sunday, the next most common day was Saturday, then Wednesday. Damage reports were most frequent on Monday, then decreased on nearly every day until reaching the lowest number on Saturday.

Most incidents involved one person. For incidents involving deaths only, 91% of the cases had one fatality, while another 8% of the events had two people killed in the same incident. For incidents involving injuries only, 68% of the cases had one injury; casualties clustered nearly the same as injuries. Males were killed by lightning 5.6 times as often as females, and were 4.9 times as likely to be injured as females.

The digital *Storm Data* listing of the locations of victims is not very precise. Of the known locations, recreation was the largest category in every region and in the US. The next largest group involved people located under trees, and the next was related to the proximity to bodies of water. The remaining categories involving small numbers of people were golfers, people involved in agricultural activities, telephones users, and people in proximity to radios and antennas.

Half of all lightning-caused damage costs were between $5,000 and $50,000 according to *Storm Data*. Comparison with other datasets shows that *Storm Data* entries tend to include more expensive widely-known events and to exclude most of the small losses.

1. INTRODUCTION

This report summarizes casualties and damages from lightning in the United States. The information comes entirely from the National Oceanic and Atmospheric Administration (NOAA) publication *Storm Data*. Features of the national distribution of lightning-caused casualties have been summarized in a variety of ways in previous publications that will be referenced in this paper. These studies include Zegel (1967), Weigel (1976), Mogil et al. (1977), Vigansky (1985), Duclos and Sanderson (1990), Duclos et al. (1990), and López and Holle (1995, 1996). Studies have also been made of lightning casualties and damages in Michigan (Ferrett and Ojala, 1992), central Florida (Holle et al., 1993), Colorado (López et al., 1995), and Rocky Mountain states (Holle et al., 1996).

Short summaries of weather impacts based on *Storm Data* have been published each year since 1990 by the Office of Meteorology in NOAA's National Weather Service. From the 1992 to 1994 summaries, Table 1 shows the average number of deaths in the United States due to four categories of thunderstorm-related weather events. During this three-year period, lightning caused 44% of the fatalities, 19% of the injuries, and 3% of the damages for all convective-weather reports in *Storm Data*. Absolute values of these numbers must be considered with caution, for reasons given in the next chapter.

When all types of weather-related casualties are examined, Table 2 shows that lightning remains near the top of the list; only flash floods and river floods combined rank higher than lightning in terms of deaths. There is a substantial number of lightning victims and damages every year. Lightning entries have the least year-to-year variability of all convective-weather causes in Table 1, and less variability than nearly all other phenomena in Table 2. The result is that the vulnerability to lightning is a constant and widespread threat to people and property during every thunderstorm season. A somewhat similar study by Dittmann (1994) used *Storm Data* to examine state-by-state flood deaths from 1959-1991.

The need for the current study and other recent examinations of lightning victims was emphasized by Emanuel et al. (1995) who stated:

> "We believe that it is time to perform an analysis of the type of electrical storms that kill people" (page 1201).

It should be mentioned that a renewed interest in medical issues concerning lightning casualties has occurred. Recent publications on lightning-related deaths and injuries include a book by Andrews et al. (1992), two complete 1995 issues of *Seminars in Neurology*, and numerous articles such as those by Andrews (1995), Cherington (1995), Cooper (1995), and Cooper and Andrews (1995).

TABLE 1. Annual averages of casualties and property damage due to convective weather (thunderstorms) during 1992-1994 (from National Weather Service, Office of Meteorology). Order is by number of deaths per year.

Convective weather type	Fatalities	Injuries	Damage ($millions)
Lightning	51	345	32
Tornadoes	47	1114	551
Thunderstorm wind	18	352	192
Hail	0	21	345

TABLE 2. Summary of 1994 weather casualties, and 30-year normals (from National Weather Service, Office of Meteorology). Order is by 30-year death rate, then by 1994 deaths.

Weather type	1994 deaths	1994 injuries	Deaths per year
Flash flood	59	33	139
River flood	32	14	
Lightning	69	484	87
Tornado	69	1067	82
Hurricane	9	45	27
Extreme temperatures	81	298	
Winter weather	31	2690	
Thunderstorm wind	17	315	
Other high wind	12	61	
Fog	3	99	
Other	6	59	
Total	388	5,165	

2. LIGHTNING REPORT DATA

Reports of damaging weather phenomena are collected monthly by local NOAA-National Weather Service offices. Individual station reports are sent to NOAA's National Climatic Data Center (NCDC) in Asheville, N.C. where *Storm Data* is assembled for the entire country. This publication has been compiled with essentially the same procedures and agencies since 1959.

The database used in this study contains all reports published in *Storm Data*. Each report contains the following information:

- Year, month, and day.
- Time in Local Standard Time (LST).
- State and county.
- Number of fatalities.
- Gender and location of fatalities.
- Number of injuries.
- Gender and location of injuries.
- Categorical amount of damage reported.

The total number of lightning-caused reports in the *Storm Data* archive during the 36 years is in Table 3. A total of 11 casualty or property-damage reports were found to be assigned to the wrong state in the digital database by cross-checking them with the two-letter state codes. The quality of the NCDC database, defined as the ratio of incidents with known time and date of occurrence to all incidents, has improved from below 40% during the 1960s to above 90% after 1987.

TABLE 3. Total lightning-related reports in *Storm Data* from 1959-1994.

Impacts	Entries
Deaths	3,239
Injuries	9,818
Casualties (deaths and injuries combined)	13,057
Property damage	19,814

Absolute values of the casualties and especially damages in Tables 1 to 3 must be considered with caution. Lightning-caused casualty and damage events are usually less spectacular and more widely dispersed in time and space than are other weather phenomena such as tornadoes and hurricanes. For this reason, lightning deaths, injuries, and damages are underreported, as found in the following studies:

* Mogil et al. (1977) found 33% more lightning deaths in Texas than *Storm Data.*
* López et al. (1993) found 28% more fatalities and 42% more injuries requiring hospitalization in Colorado than *Storm Data*.
* Holle et al. (1996) found 367 times as many insured personal property claims due to lightning in three western states than were listed during the same years in *Storm Data.*
* Lushine (1996) found 31% more fatalities in Florida than *Storm Data.*

The results of the latter report lead to the conclusion that lightning-caused losses are similar to, or exceed other phenomena in Table 1. When other unquantified losses are taken into account, lightning may be the largest cause of damages and have less change from year to year than most other weather types.

Factors contributing to underreporting include the following:

- Indirect lightning casualties are often reported by the medical system as having lightning as the secondary rather than the primary cause (Mogil et al., 1977).
- Reliance on newspaper clipping services for lightning events entered in *Storm Data* by the National Weather Service (López et al., 1993).
- The typical lightning casualty usually affects only one individual.

However, the only consistent source of data on lightning deaths, injuries, and damages for several recent decades has been *Storm Data*. With the exception of 106 damage entries that were miscoded in the year 1989 (Section 12), the *Storm Data* information will be used in the present report without modification.

3. VARIATIONS BY STATE IN REPORTED FREQUENCIES

A. DEATHS AND INJURIES COMBINED (CASUALTIES)

Section 3 describes variations among states in actual frequencies of lightning reports by the use of maps and tables. This section shows results without population weighting; population is included in section 4. Data used to develop the following maps and tables are given at the end of section 3.

The sum of fatalities and injuries together is termed casualties. Figures 1 and 2 map the sum of lightning-caused deaths and injuries. Tables 4 and 5 give the top and bottom ten locations for deaths and injuries combined. All states are shown in descending order by the number of casualties in Figure 3. The largest numbers of casualties are in Florida, Michigan, Pennsylvania, North Carolina, and New York. Other high numbers are found in the southern and eastern regions of the US, and some states in the northeastern US where there is a large population. Also evident is a large number of casualties in the mountainous, dry states of Colorado, New Mexico, and Arizona. The smallest numbers of lightning casualties are in Alaska (none), Hawaii, the District of Columbia, northwest US states, Puerto Rico, and several small eastern states. Casualties by county for Colorado are in López et al. (1995).

There are 13,057 *Storm Data* casualties from 1959 to 1994 (Table 3 and Figures 1 to 3) for an average of 363 per year. The National Lightning Detection Network identified an average of 21,746,000 cloud-to-ground flashes per year in the US from 1992 to 1995 (Orville, 1997). Assuming this four-year average to be representative, the result is a casualty every 60,000 flashes. Since around 70% of the flashes were detected, about 86,000 flashes occur for each casualty. A similar estimate can be made for Arizona from López et al. (1997). Making corrections for season, analysis area, and detection efficiency, about 800,000 flashes per year occur in Arizona, while there were 4.5 casualties per year from 1959-1994 (Table 12). The resulting ratio in Arizona is one casualty for every 175,000 flashes; a lower frequency is reasonable since there usually is less lightning in Arizona compared to the rest of the US (Orville, 1991; Orville et al., 1997).

TABLE 4. Ten US locations with the most casualties (deaths and injuries combined) due to lightning from 1959-1994 in *Storm Data.*

Rank	State	No. of deaths and injuries
1	Florida	1523
2	Michigan	732
3	Pennsylvania	644
4	North Carolina	629
5	New York	577
6	Ohio	545
7	Texas	498
8	Tennessee	473
9	Georgia	410
10	Colorado	394

TABLE 5. As in Table 4 for the least casualties.

Rank	State	No. of deaths and injuries
43	Delaware	42
44	Washington	40
45	Puerto Rico	36
46	North Dakota	35
47	Vermont	30
48	Oregon	26
49	District of Columbia	23
50	Nevada	18
51	Hawaii	4
52	Alaska	0

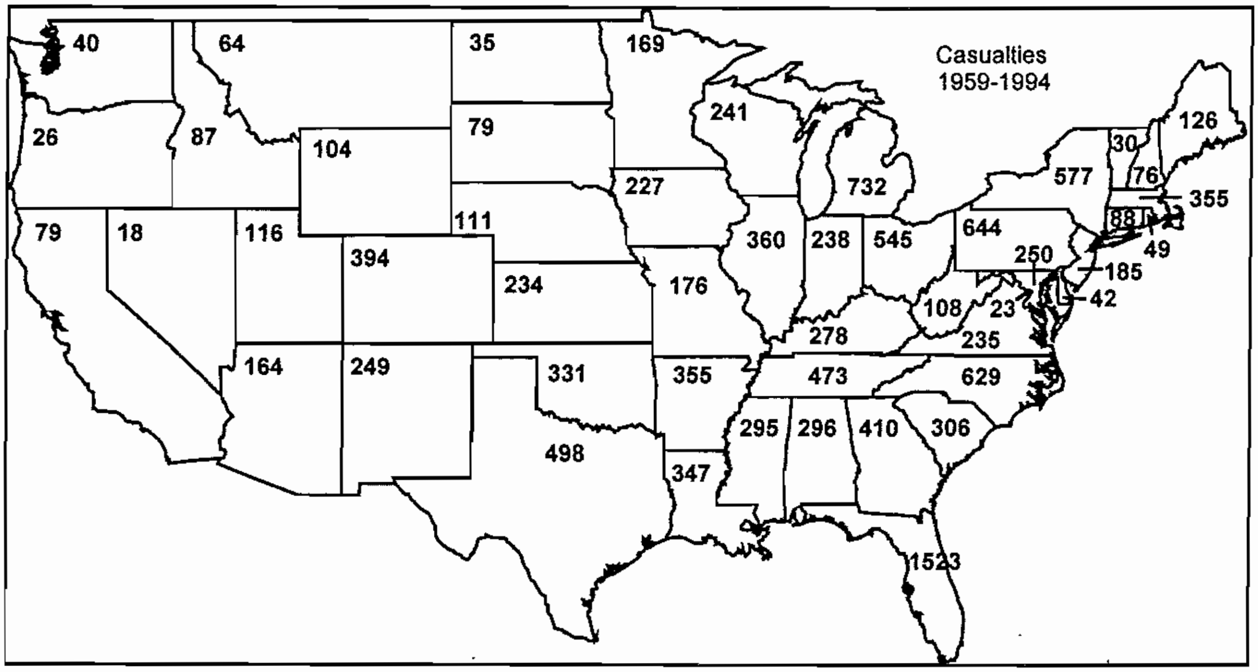

FIGURE 1. US map of number of lightning casualties (deaths and injuries combined) by state from 1959 to 1994.

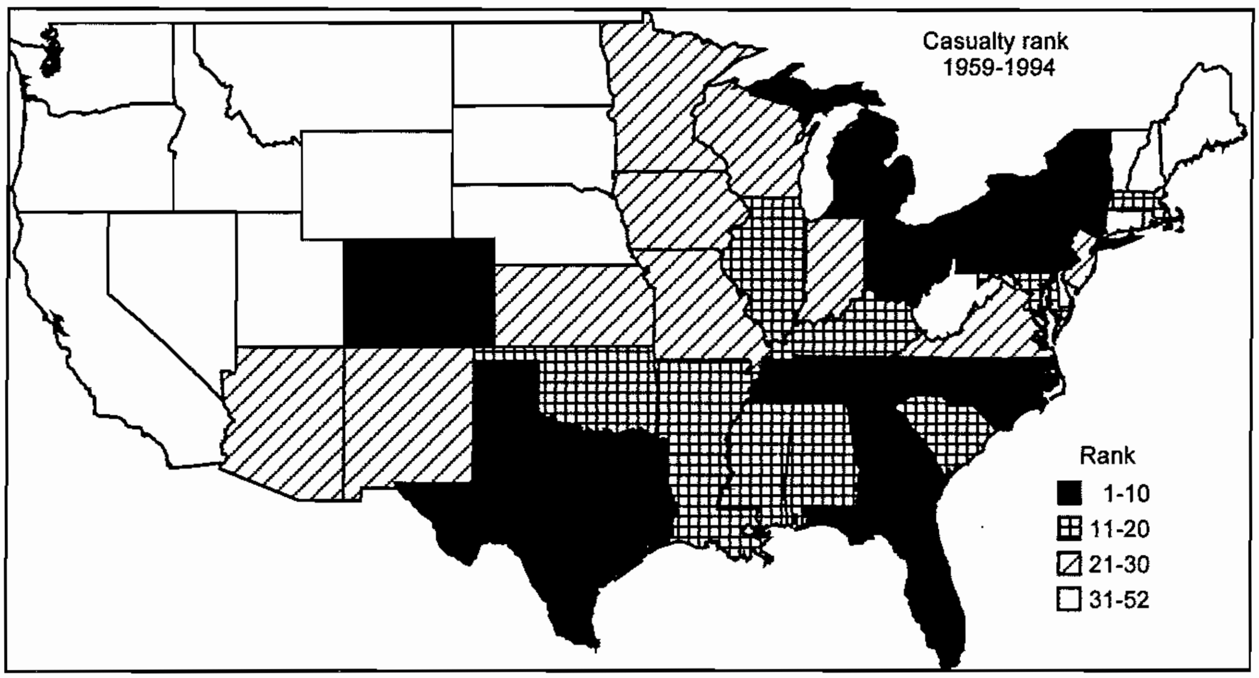

FIGURE 2. US map of lightning casualties (deaths and injuries combined) ranked by state from 1959 to 1994.

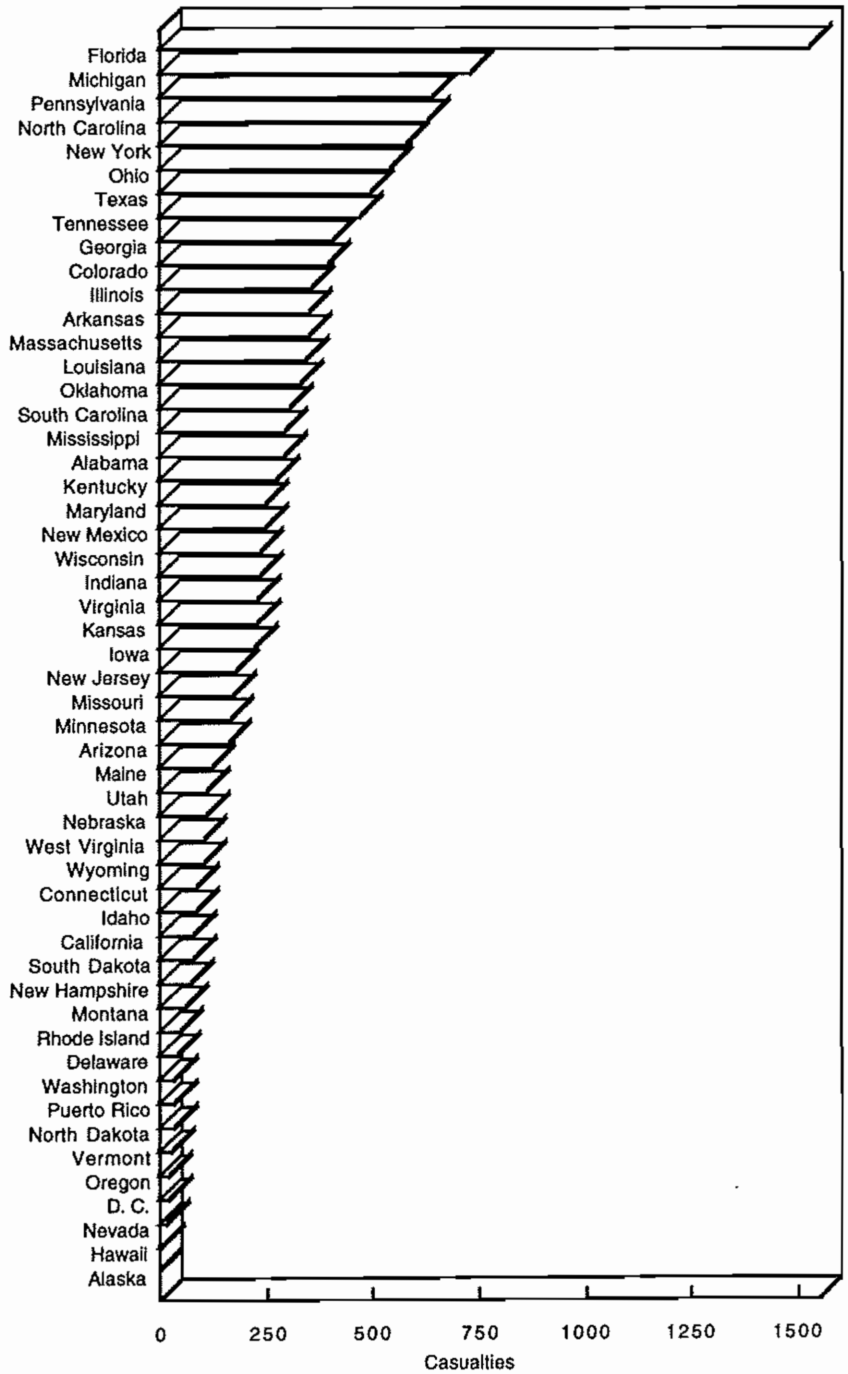

FIGURE 3. Number of lightning casualties (deaths and injuries combined) ordered by state from 1959 to 1994.

B. DEATHS

Maps of lightning-caused fatalities are shown in Figures 4 and 5, and states with the most and least deaths in Tables 6 and 7. Florida has twice as many deaths compared to any other state in *Storm Data*.

A major change from previous results for casualties is the absence of Michigan in the highest total of deaths (Table 6), indicating that injuries have been more commonly-reported than deaths in Michigan. Otherwise, the same states are in the first-ten list for both deaths and casualties, although in a different order. Also, Maryland and Arkansas for deaths replace Georgia and Colorado on the casualty list. The large Maryland entry is mainly due to the 81 deaths in a lightning-caused aircraft crash in 1963.

In terms of the least lightning-caused fatalities, there were no deaths in Hawaii and Alaska. The bottom-ten list in Table 7 includes the same states as casualties (Table 5), except New Hampshire and Rhode Island replace Delaware and Puerto Rico.

Lightning deaths from *Storm Data* at specific locations in the US were shown from 1959 to 1965 by Zegel (1967). *Storm Data* deaths were plotted by state in Mogil et al. (1977) for 1968 to 1976, and Duclos and Sanderson (1990) for 1968 to 1985.

Pakiam et al. (1981) plotted each fatality on a map of Singapore. Coates et al. (1993) for Australia and Gourbiere et al. (1997) for France showed maps of lightning deaths divided by political boundaries in formats similar to Figure 5. In the US, state maps of lightning deaths by county have been compiled for North Carolina (Langley et al., 1991), Michigan (Ferrett and Ojala, 1992), and Colorado (López et al., 1995).

There were 3239 *Storm Data* deaths in the US from 1959 to 1994 (Table 3 and Figures 4 and 5) for an average of 90 per year. The same analysis can be made for deaths using the network-detected ground strikes as in the previous section for casualties. The result is one death for every 345,000 flashes in the US.

TABLE 6. Ten US locations with the most deaths due to lightning from 1959-1994 in *Storm Data*.

Rank	State	Number of deaths
1	Florida	345
2	North Carolina	165
3	Texas	164
4	New York	128
5	Tennessee	124
6	Louisiana	116
7	Maryland	116
8	Ohio	115
9	Arkansas	110
10	Pennsylvania	109

TABLE 7. Ten US locations with the least deaths due to lightning from 1959-1994 in *Storm Data*.

Rank	State	Number of deaths
43	Vermont	12
44	North Dakota	11
45	New Hampshire	8
46	Oregon	7
47	Nevada	6
48	District of Columbia	5
49	Rhode Island	4
50	Washington	3
51	Alaska	0
52	Hawaii	0

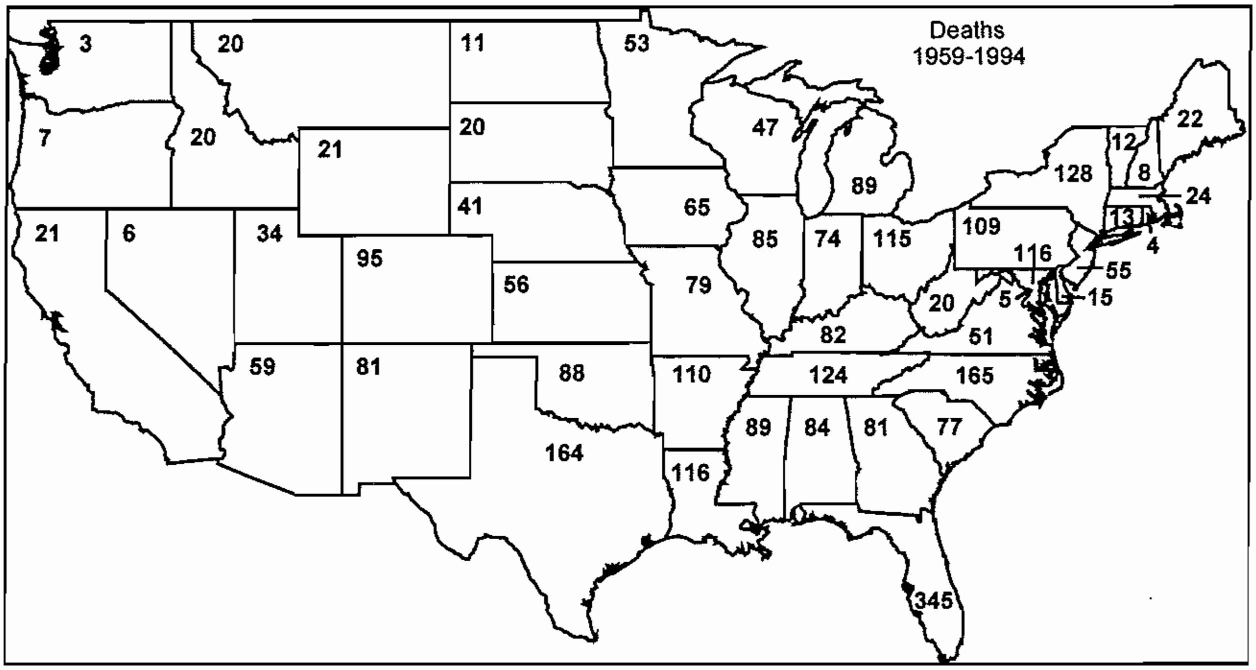

FIGURE 4. US map of number of lightning deaths by state from 1959 to 1994.

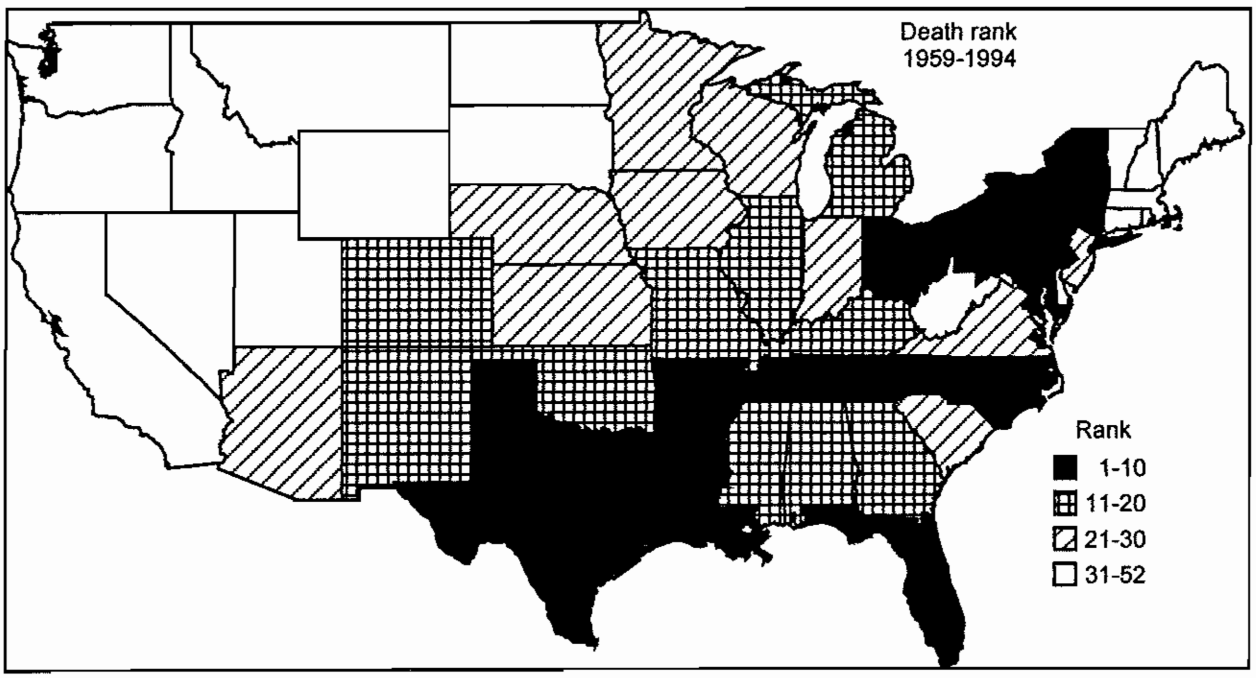

FIGURE 5. US map of lightning deaths ranked by state from 1959 to 1994.

C. INJURIES

Figures 6 and 7 show maps of injuries by state. Locations with the most and least injuries are in Tables 8 and 9. Florida had more injuries than other state since 1959, as well as deaths (Table 6), and therefore casualties (Table 4).

The same states appear on the first-ten list of fatalities in Table 8 except for two changes. Michigan is second in injuries but twelfth in deaths. Also, Georgia and Massachusetts on the injury list replace Arkansas and Maryland on the fatality list. The least injuries are in Alaska (0), Hawaii (4), Puerto Rico (6), and other western states and small eastern states.

The large number of Michigan injuries is due in part to two exceptional events (Ferrett and Ojala, 1992). During one *Storm Data* case in August 1975, 90 people were injured when lightning struck near the center of a campground at Leslie, Michigan. In June 1979, 45 National Guard soldiers suffered minor injuries when lightning struck their camp near Grayling, Michigan. A US map of injuries was shown for 1968 to 1976 by Mogil et al. (1977), and a state map of injuries by Colorado county was compiled by López et al. (1995).

Most states have more injuries than deaths; the US average ratio is 2.54 injuries per death in *Storm Data* from 1959 to 1994. But Missouri had only slightly more injuries (93) than deaths (78), and Puerto Rico had 6 injuries but 30 deaths; a few other locations approach a 1:1 ratio. A map of the injury to death ratio by state (not shown) has no pattern. In Puerto Rico, the authors found that many lightning injuries occur there but are not widely known, while deaths are usually reported to the National Weather Service and included in *Storm Data*. If this is typical, a low ratio of injuries to fatalities in a location may indicate underreporting of injuries, such that deaths are better reported. Recall that López et al. (1993) found a greater underreporting of injuries requiring hospitalization (42%) than the underreporting of deaths (28%) in Colorado.

There were 9818 *Storm Data* injuries in the US from 1959 to 1994 (Table 3 and Figures 6 and 7). The same analysis for injuries using network-detected lightning as in previous sections results in one US injury for every 114,000 flashes.

TABLE 8. Ten US locations with the most injuries due to lightning from 1959-1994 in *Storm Data.*

Rank	State	Number of injuries
1	Florida	1178
2	Michigan	643
3	Pennsylvania	535
4	North Carolina	464
5	New York	449
6	Ohio	430
7	Tennessee	349
8	Texas	334
9	Massachusetts	331
10	Georgia	329

TABLE 9. Ten US locations with the least injuries due to lightning from 1959-1994 in *Storm Data.*

Rank	State	Number of injuries
43	Washington	37
44	Delaware	27
45	North Dakota	24
46	Oregon	19
47	Vermont	18
48	District of Columbia	18
49	Nevada	12
50	Puerto Rico	6
51	Hawaii	4
52	Alaska	0

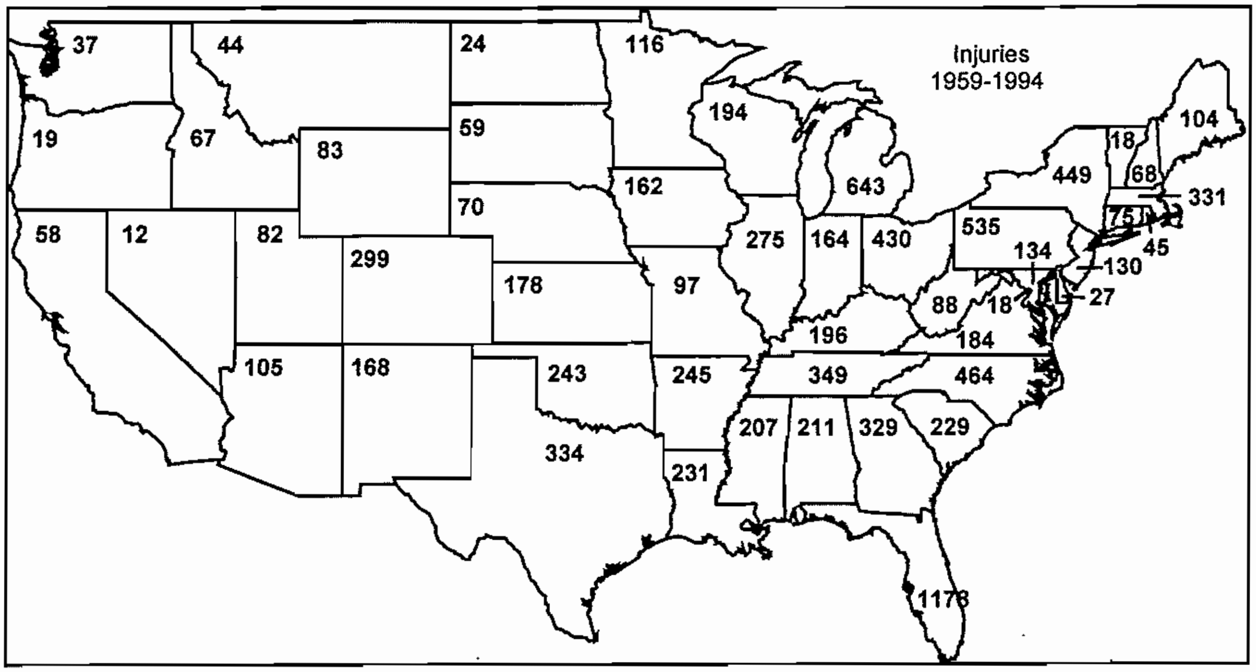

FIGURE 6. US map of number of lightning injuries by state from 1959 to 1994.

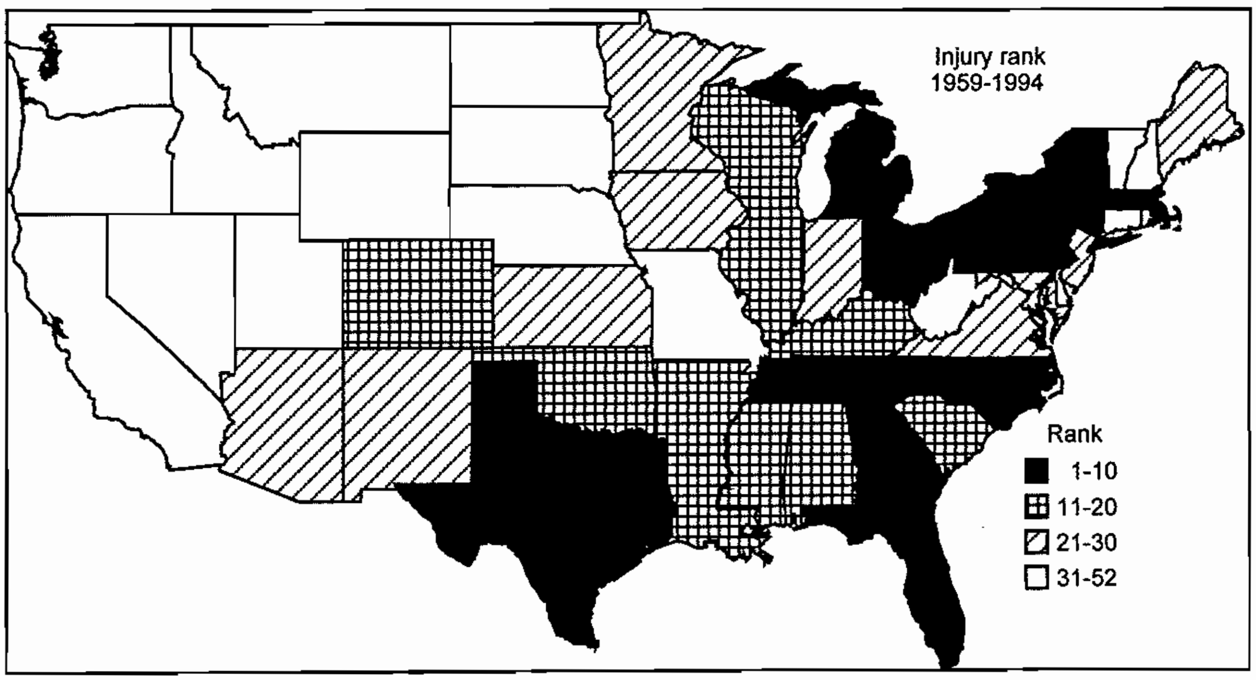

FIGURE 7. US map of lightning injuries ranked by state from 1959 to 1994.

D. DAMAGE REPORTS

Maps of damage reports are in Figures 8 and 9 by state. Locations with the most and least damage reports are in Tables 10 and 11.

It is apparent that damage reports in *Storm Data* are distributed very differently than are deaths and/or injuries. A high concentration of damage reports is evident over the plains from South Dakota to Texas. The highest number of damage reports is from Pennsylvania, where less than half as many casualties were reported as in Florida. In contrast, Florida is first on all casualty lists but is not high on the list of damages. Seven of the ten states with the highest damage counts are on the first-ten lists for casualties, deaths, or injuries. While Kansas, Oklahoma, and South Carolina rank in the first eight for damages, they are not in the top-ten list for any casualty category.

The least damage reports are from Alaska (3), Puerto Rico (4), and many of the same locations as in the casualty lists. An exception is the small number of damage reports from New Mexico, a state with a high number of deaths (Figure 4).

In the US, state maps of lightning damages by county have been compiled for Michigan (Ferrett and Ojala, 1992), Colorado (López et al., 1995), and Colorado, Utah and Wyoming (Holle et al., 1996).

There is a weakly-defined geographical pattern (not shown) in the ratio of damage reports to casualties in *Storm Data*. The damage/casualty report ratio was near one, or less, in all southwestern states, and several southeastern states including Florida. The northwest half of the US tended to have nearly two damage reports for every casualty report. Whether the ratio is influenced by accurate reporting of every death or injury, or whether the reporting system in some states is not very complete in reporting damages is unknown.

It is also unknown why there should be any pattern since damage reports are so greatly underreported (Section 2). Damage reports in *Storm Data* are underreported by as much as 367:1, as described in Section 2 based on insurance claims in Holle et al. (1996). Therefore, rates of flashes per damage report cannot be made reliably from the available database as was done for casualties, deaths, and injuries in previous sections.

TABLE 10. Ten US locations with the most damage reports due to lightning from 1959-1994 in *Storm Data*.

Rank	State	Number of damage reports
1	Pennsylvania	1441
2	Kansas	1182
3	New York	1005
4	North Carolina	960
5	Oklahoma	826
6	Michigan	814
7	Tennessee	764
8	South Carolina	717
9	Texas	689
10	Georgia	656

TABLE 11. Ten US locations with the least damage reports due to lightning from 1959-1994 in *Storm Data*.

Rank	State	Number of damage reports
43	Arizona	84
44	Delaware	83
45	California	60
46	Washington	56
47	New Mexico	54
48	District of Columbia	14
49	Hawaii	14
50	Nevada	11
51	Puerto Rico	4
52	Alaska	3

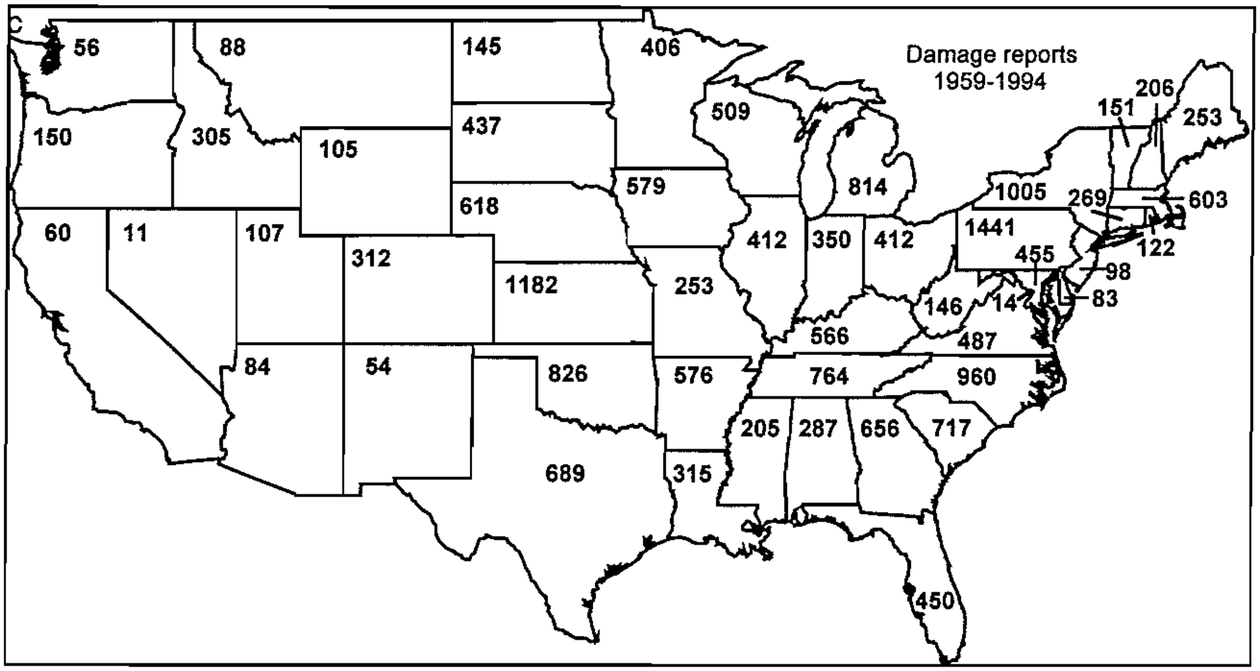

FIGURE 8. US map of number of lightning damage reports by state from 1959 to 1994.

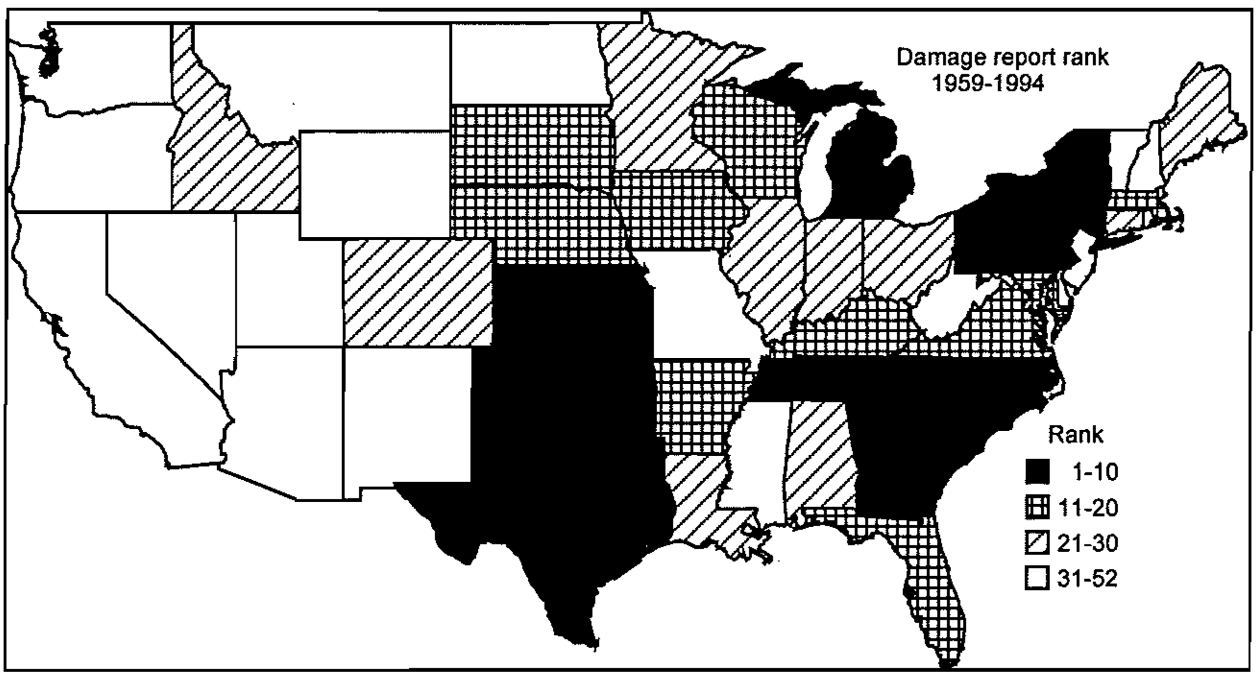

FIGURE 9. US map of lightning damage reports ranked by state from 1959 to 1994.

E. SUMMARY

Table 12 provides the detailed list of reported frequencies and corresponding ranks of fatalities, injuries, casualties, and damage reports for all states and other locations in the dataset. Information in this table was used to develop the preceding maps and tables.

Florida led the nation in deaths, injuries, and therefore casualties, over all other locations by a wide margin. States with high numbers of casualties (Figures 1, 2) tended to be in the following categories:

- Florida--very frequent casualties and a sizable population.
- Southeast and southern plains--frequent casualties and medium to large populations (Alabama, Georgia, Mississippi, South Carolina, Tennessee, Texas).
- Midwest and northeast--densely populated (Michigan, New York, Ohio).
- Southern Rockies--less populated than many states (Arizona, Colorado, New Mexico).

The largest number of damage reports came from Pennsylvania, but it had less than half as many casualties as Florida. North Carolina had uniformly high frequencies in all categories – second in deaths, fourth in injuries, and fourth in damages. In contrast, Kansas was second in damage reports but twenty-fifth in deaths and twenty-second in injuries. There were a few locations, such as Alaska, Hawaii, Puerto Rico, the District of Columbia, and Nevada, with very few casualties and damage reports over the 36-year period.

Data from recent years collected by the US National Lightning Detection Network results in a rough estimate of one lightning casualty for every 86,000 flashes. A similar method gives an estimate of one death for about every 345,000 flashes, and an injury for about every 114,000 flashes.

TABLE 12. Lightning fatalities, injuries, and damage reports, and their ranks, for all states, the District of Columbia, and Puerto Rico from 1959 to 1994.

State	Fatalities		Injuries		Casualties		Damage reports	
	No.	Rank	No.	Rank	No.	Rank	No.	Rank
Alabama	84	16	211	17	295	18	287	28
Alaska	0	51	0	52	0	52	3	52
Arizona	59	24	105	29	164	30	84	43
Arkansas	110	9	245	13	355	12	576	14
California	21	35	58	40	79	38	60	45
Colorado	95	11	299	11	394	10	312	26
Connecticut	13	42	75	35	88	36	269	29
Delaware	15	41	27	44	42	43	83	44
District of Columbia	5	48	18	48	23	49	14	48
Florida	345	1	1178	1	1523	1	450	19
Georgia	81	18	329	10	410	9	656	10
Hawaii	0	52	4	51	4	51	14	49
Idaho	20	37	67	38	87	37	305	27
Illinois	85	15	275	12	360	11	412	21
Indiana	74	22	164	24	238	23	350	24
Iowa	65	23	162	25	227	26	579	13
Kansas	56	25	178	22	234	25	1182	2
Kentucky	82	17	196	19	278	19	566	15
Louisiana	116	6	231	15	347	14	315	25
Maine	22	34	104	30	126	31	253	30
Maryland	116	7	134	26	250	20	455	18
Massachusetts	24	33	331	9	355	13	603	12
Michigan	89	12	643	2	732	2	814	6
Minnesota	53	27	116	28	169	29	406	23
Mississippi	89	13	207	18	296	17	205	33
Missouri	79	20	97	31	176	28	253	31
Montana	20	38	44	42	64	41	88	42
Nebraska	41	30	70	36	111	33	618	11
Nevada	6	47	12	49	18	50	11	50
New Hampshire	8	45	68	37	76	40	206	32
New Jersey	55	26	130	27	185	27	98	41
New Mexico	81	19	68	23	249	21	54	47
New York	128	4	449	5	577	5	1005	3
North Carolina	165	2	464	4	629	4	960	4
North Dakota	11	44	24	45	35	46	145	37
Ohio	115	8	430	6	545	6	412	22
Oklahoma	88	14	243	14	331	15	826	5
Oregon	7	46	19	46	26	48	150	35
Pennsylvania	109	10	535	3	644	3	1441	1
Puerto Rico	30	32	6	50	36	45	4	51
Rhode Island	4	49	45	41	49	42	122	38
South Carolina	77	21	229	16	306	16	717	8
South Dakota	20	39	59	39	79	39	437	20
Tennessee	124	5	349	7	473	8	764	7
Texas	164	3	334	8	498	7	689	9
Utah	34	31	82	34	116	32	107	39
Vermont	12	43	18	47	30	47	151	34
Virginia	51	28	184	21	235	24	487	17
Washington	3	50	37	43	40	44	56	46
West Virginia	20	40	88	32	108	34	146	35
Wisconsin	47	29	194	20	241	22	509	16
Wyoming	21	36	83	33	104	35	105	40
United States	3239		9818		13,057		19,814	

4. VARIATIONS BY STATE WEIGHTED BY POPULATION

Section 3 showed results when actual frequencies of *Storm Data* entries were used. Many states with high frequencies of casualties and damage are the most populous, such as New York and other northeast states. However, some states such as Colorado and New Mexico are not so populous but also had large numbers of lightning-caused deaths and/or injuries.

To compensate for this effect, population was considered. Figure 10 shows the ranks by state of the population during the *Storm Data* record. These values were found by averaging the decennial census populations in 1960, 1970, 1980, and 1990. The average populations were then used to calculate rates of casualties, deaths, injuries and damages for each state.

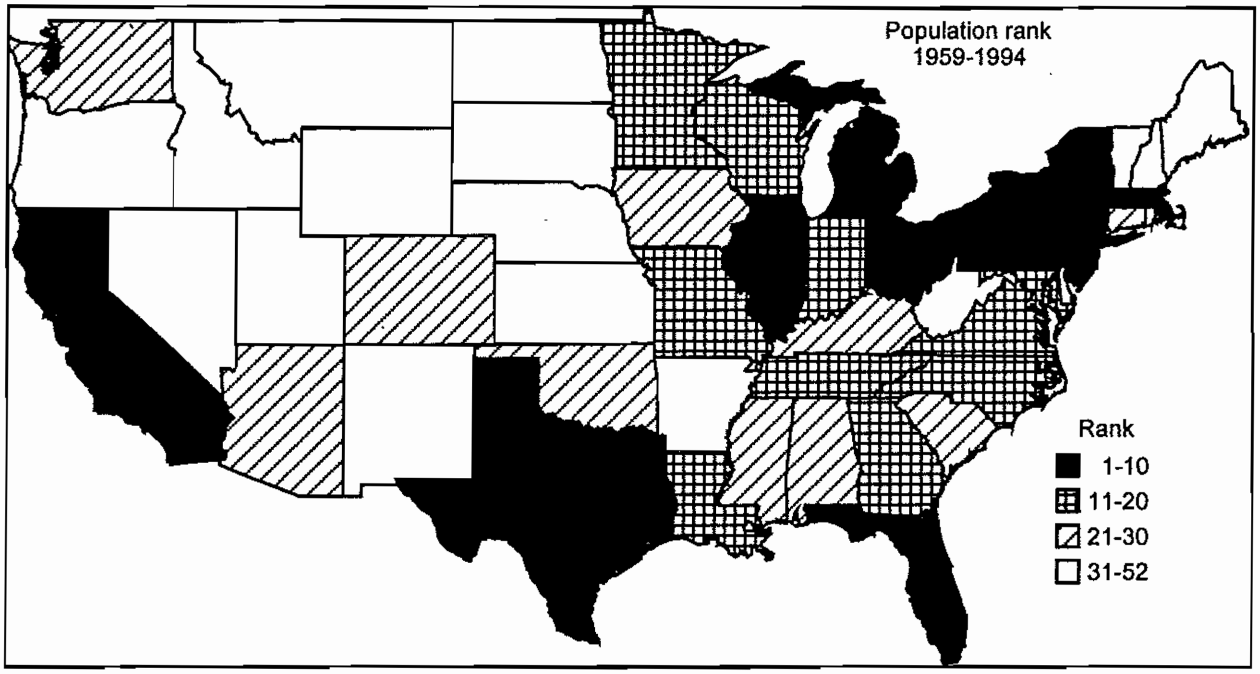

FIGURE 10. US map of average population ranked by state from 1959 to 1994.

A. DEATH AND INJURY (CASUALTY) RATE PER POPULATION

States with the highest rates of lightning-caused casualties per million people are shown in Figure 11 and Table 13. Table 14 lists the states with the lowest casualty rates.

There are major differences between these rates and reported frequencies of casualties in Figures 1 and 2, and Table 4. States are also shown in descending order by number of casualties per million people in Figure 12.

The highest rates of casualties were in Wyoming and New Mexico, while these states were only 35th and 21st, respectively, in actual reports. These states are less populous than most, but had many casualties. It must be noted that in section 5 of this paper, Wyoming will be shown to have had almost all of its casualties in the 1960s and 1970s, and almost none since then.

The only states in the first-ten list of both casualties and casualty rate (Table 4) are Florida, Colorado, and North Carolina. Florida was first in all previous lists of casualties, while it is third in casualty rate. Colorado was tenth in reported casualties, and fifth in casualty rate; North Carolina was fourth and tenth in rate.

The net effect of taking into account the population is a shift from the populous eastern states to the Rocky Mountain and plains states. Many of the southeast states have a high ranking in both Figures 2 and 11.

The lowest casualty rates in Table 14 continue to be in nearly the same locations. There is a dominance of west-coast states and small eastern states in the list of reports in Table 5 and casualty rate in Table 14.

Casualty rates for each state by population over the US were also shown by Ferrett and Ojala (1992) from 1959 to 1987, and López and Holle (1995) from 1959 to 1990. These studies categorized results by increments of casualty rates rather than the ranks in this report. López et al. (1995) showed casualty rates by county in Colorado.

Data from the National Lightning Detection Network can be used to take into account both population and lightning activity. For the US, a rate is found of 7.7 casualties per million people per 100 million flashes.

TABLE 13. Ten US locations with the highest rates of lightning-caused casualties (deaths and injuries combined) per million people from 1959-1994 in *Storm Data.*

Rank	State	Casualties/ million people/year
1	Wyoming	7.21
2	New Mexico	5.76
3	Florida	4.91
4	Arkansas	4.73
5	Colorado	4.28
6	Mississippi	3.47
7	Oklahoma	3.31
8	Maine	3.25
9	South Dakota	3.21
10	North Carolina	3.16

TABLE 14. As in Table 13 for lowest casualty rates.

Rank	State	Casualties/ million people/year
43	Illinois	0.91
44	Connecticut	0.82
45	Nevada	0.76
46	New Jersey	0.71
47	Puerto Rico	0.44
48	Oregon	0.31
49	Washington	0.29
50	California	0.10
51	Hawaii	0.10
52	Alaska	0

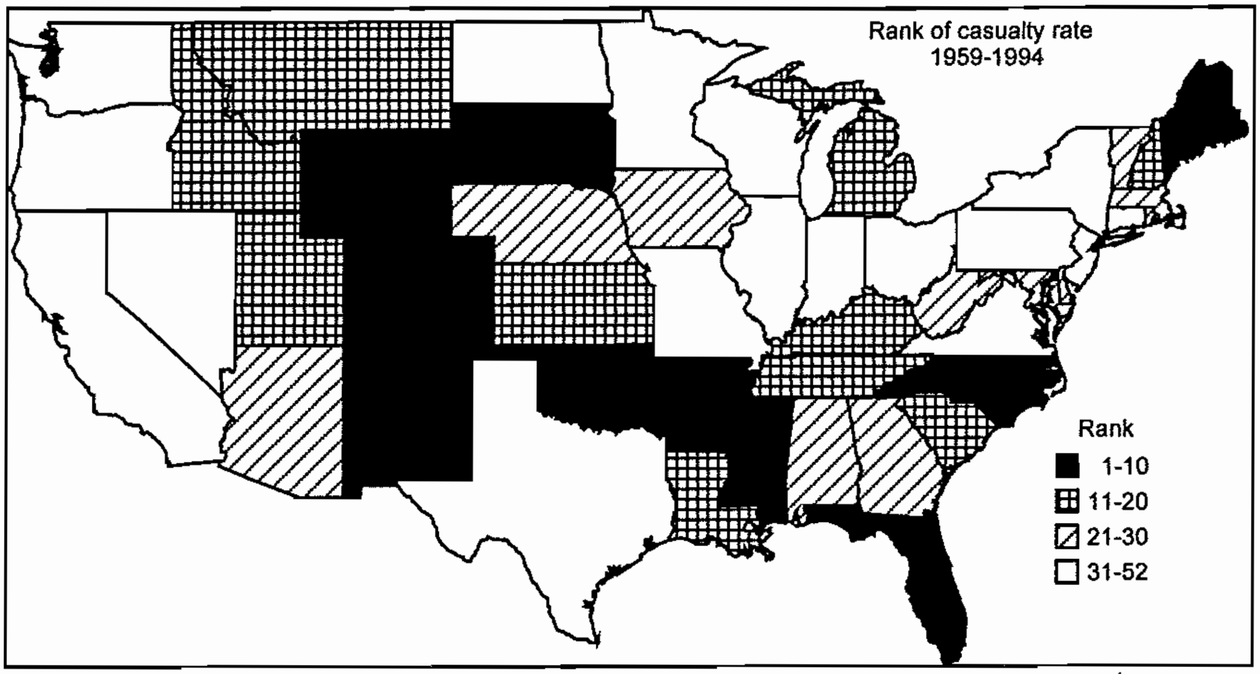

FIGURE 11. US map of rates of lightning casualties (deaths and injuries combined) ranked by state from 1959 to 1994.

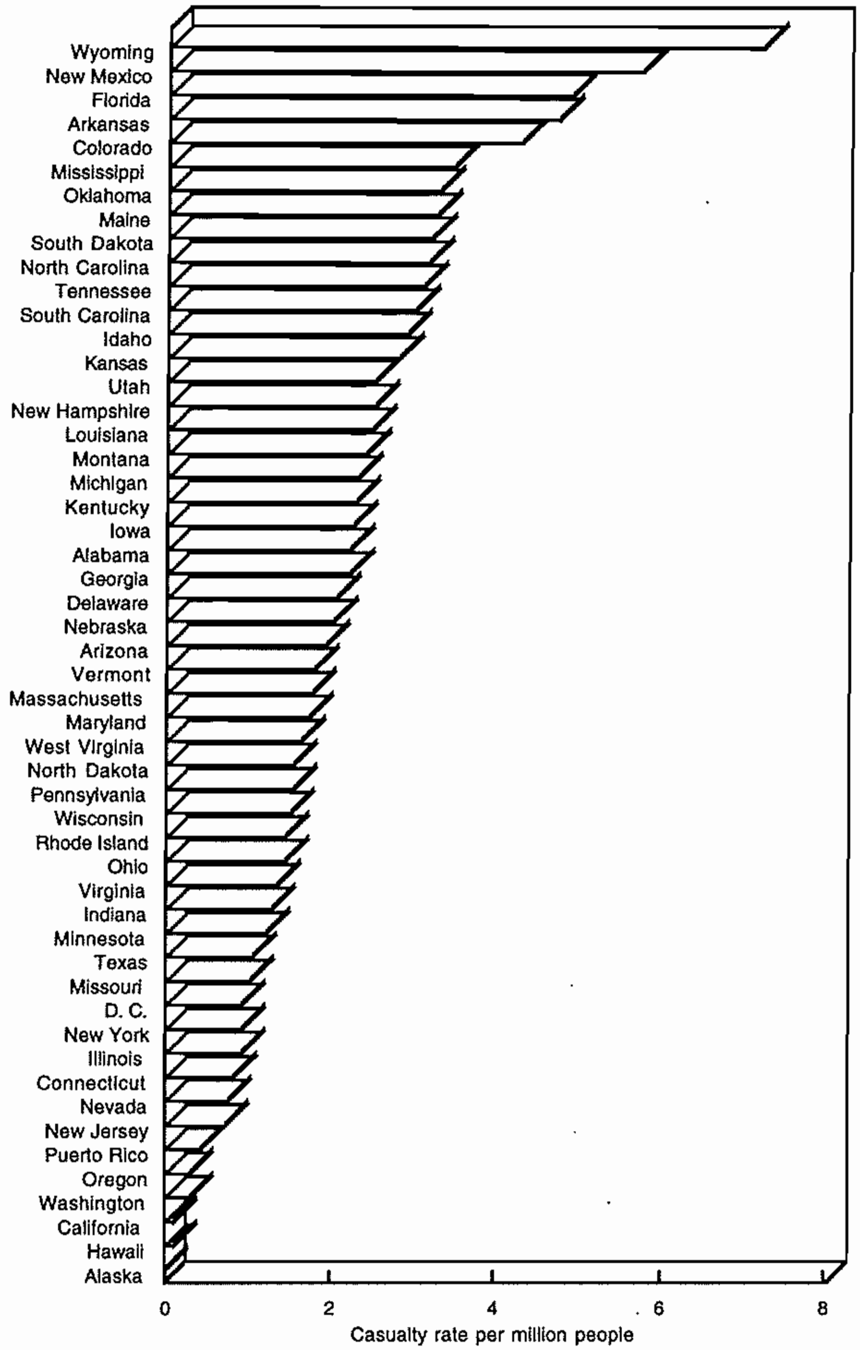

FIGURE 12. Rate of lightning casualties (deaths and injuries combined) per population ordered by state from 1959 to 1994.

B. DEATH RATE PER POPULATION

States with highest rates of lightning-caused fatalities are shown in Figure 13 and Table 15. Table 16 lists states with the lowest death rates.

New Mexico and Wyoming had the highest lightning-caused death rates, as for casualty rate in Table 13, except for exchanging first and second places. Wyoming had a high death rate in the first half of the record but not the last half (section 5 of this paper), while New Mexico consistently had high rankings. Louisiana replaces Maine compared to casualty rate results. Most states with highest death rates are less populous than other states, or have a medium number of people for a state. The exception is Florida, where there is both a large number of inhabitants and a high lightning death rate.

Lowest death rates (Table 16) were in Alaska, Hawaii, and mainly Pacific-coast or densely-populated east-coast states. These locations are often the same as states with a small number of reported deaths in Table 7.

Similar maps of death rates per state population based on *Storm Data* were shown by Zegel (1967) from 1959 to 1965, by Duclos and Sanderson (1990) from 1968 to 1985, as well as by Ferrett and Ojala (1992) from 1959 to 1987. These results were categorized by increments rather than ranks. Mogil et al. (1977) listed the fatality rate by state in a table from 1968 to 1976.

The United States average was 0.41 deaths per million people per year from 1959 through 1994. This value is an order of magnitude larger than the 0.03 per 100,000 people per year calculated by Coates et al. (1993) in Australia from 1960-1979.

TABLE 15. Ten US locations with the highest rates of lightning-caused deaths per million people from 1959-1994 in *Storm Data*.

Rank	State	Deaths/ million people/year
1	New Mexico	1.88
2	Wyoming	1.47
3	Arkansas	1.46
4	Florida	1.10
5	Mississippi	1.04
6	Colorado	1.04
7	Oklahoma	0.88
8	North Carolina	0.84
9	Louisiana	0.83
10	South Dakota	0.81

TABLE 16. As in Table 15 for the lowest death rates.

Rank	State	Deaths/ million people/year
43	New York	0.20
44	District of Columbia	0.20
45	Connecticut	0.12
46	Rhode Island	0.12
47	Massachusetts	0.12
48	Oregon	0.08
49	California	0.03
50	Washington	0.02
51	Hawaii	0
52	Alaska	0

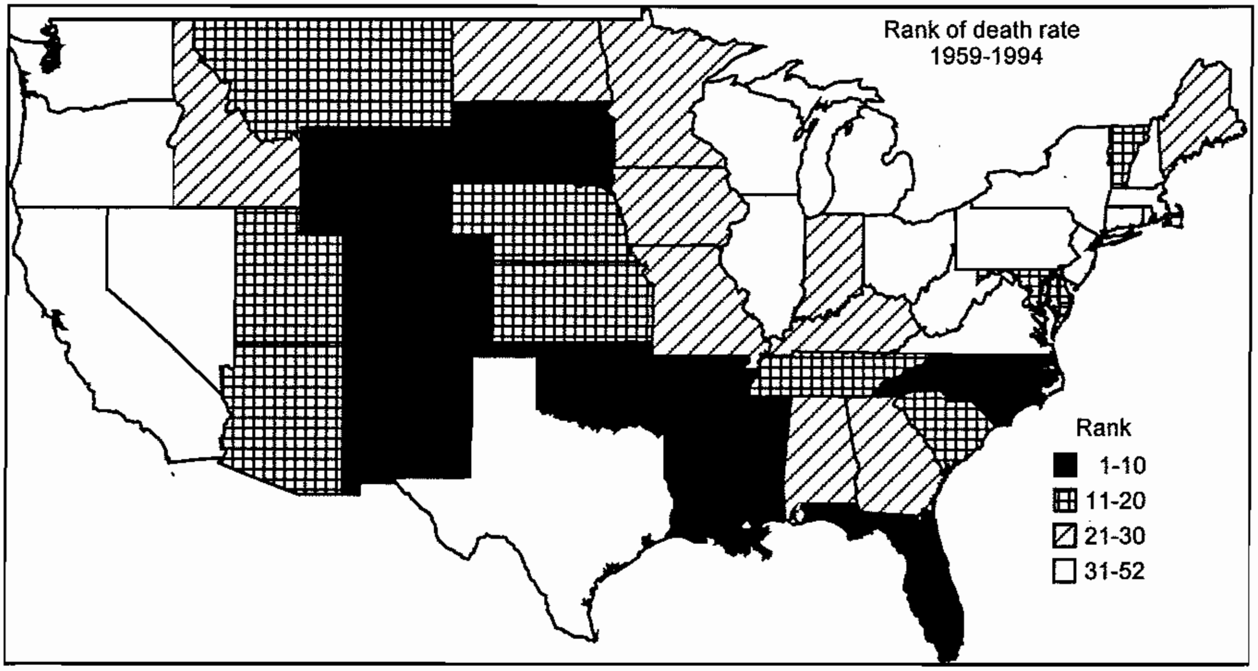

FIGURE 13. US map of rates of lightning deaths ranked by state from 1959 to 1994.

C. INJURY RATE PER POPULATION

States with highest rates of lightning-caused injuries are in Figure 14 and Table 17. Table 18 lists states with the lowest injury rates.

Locations with the highest rates of injuries (Table 17) are almost identical with those with high casualty rates in Table 13. The list is almost entirely different from reported injuries in Table 8; Florida and North Carolina are the only states in both tables. States with high injury rates have smaller than average to average populations, while the largest reported frequencies of injuries are from populous states.

Lowest injury rates (Table 18) are from similar locations as low casualty rates in Table 14 – Alaska, Hawaii, west coast states, and small east coast states. The one exception is Missouri, where less injuries than deaths have been reported (Table 12); nearly all other states have more injuries than deaths as summarized in section 3C.

Ferrett and Ojala (1992) showed similar injury rates per population from 1959-1987 based on *Storm Data*. Their results were in increments rather than ranks.

TABLE 17. Ten US locations with the highest rates of lightning-caused injuries per million people from 1959-1994 in *Storm Data*.

Rank	State	Injuries/ million people/year
1	Wyoming	5.74
2	New Mexico	3.89
3	Florida	3.80
4	Arkansas	3.26
5	Colorado	3.24
6	Maine	2.68
7	Mississippi	2.42
8	Oklahoma	2.42
9	South Dakota	2.40
10	North Carolina	2.32

TABLE 18. As in Table 17 for lowest injury rates.

Rank	State	Injuries/ million people/year
43	Illinois	0.69
44	Missouri	0.54
45	Nevada	0.52
46	New Jersey	0.49
47	Washington	0.27
48	Oregon	0.23
49	Hawaii	0.10
50	Puerto Rico	0.07
51	California	0.07
52	Alaska	0

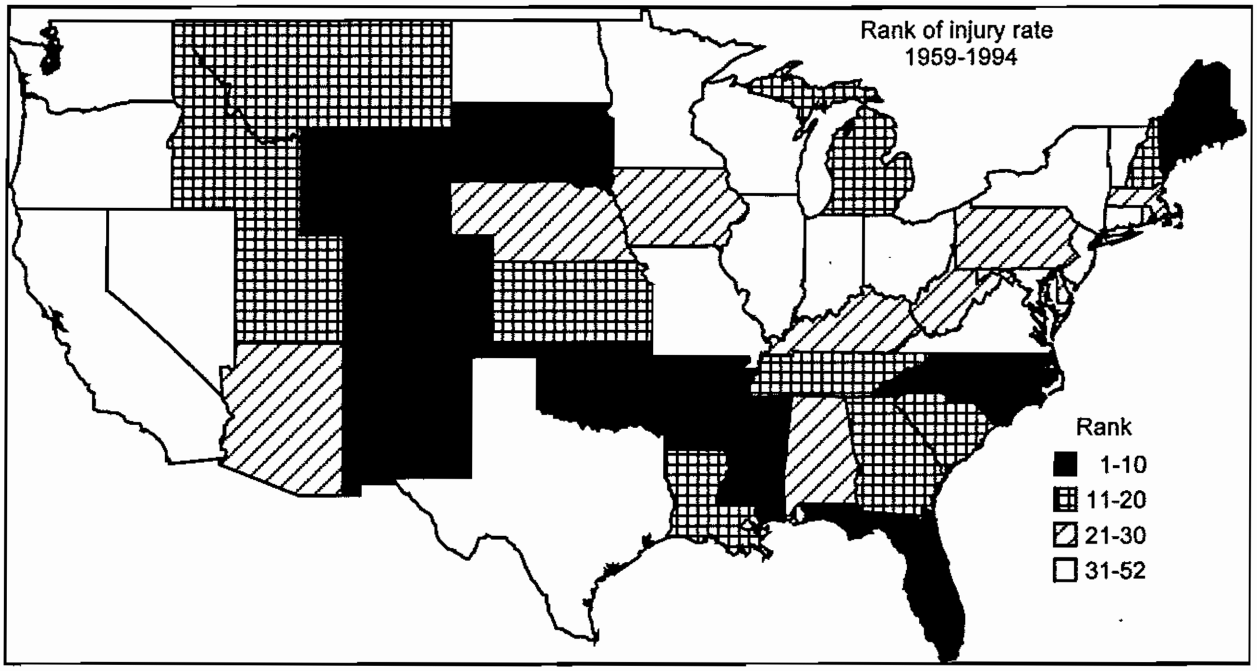

FIGURE 14. US map of rates of lightning injuries ranked by state from 1959 to 1994.

D. DAMAGE REPORT RATE PER POPULATION

States with the highest rates of lightning-caused damage reports are in Figure 15 and Table 19. Table 20 lists states with lowest damage rates. No previous publication has shown US maps of damage reports normalized by population.

A swath of high rates of damage reports is located in Figure 15 from North Dakota to Oklahoma and Arkansas. This region also had high numbers of reported damages in Figure 8 with two exceptions. North Dakota did not have many actual reports, but this less populous state became twelfth in terms of damage rate. While Texas had numerous reports, its damage rate became small due to its large population. Other populous states in the first ten in terms of numbers of reports (Table 10), New York, Pennsylvania, and Michigan, rank much lower in the rate of damage reports (Table 26).

As noted in section 3D, there was usually only one damage report for each casualty in southwestern states, Florida, and several southeast states. The northwest half of the US tended to have about two damage reports for each casualty. These unaccountable variations by state result in the map of Figure 15 that does not seem to have any pattern except for high rates along the plains.

Lowest damage rates (Table 20) are mostly from the same locations as states with low casualty rates in Table 14. A notable exception is New Mexico, where there was a very low rate of damage reports (41st) while it ranked first or second in the rate of casualties, deaths, and injuries.

TABLE 19. Ten US locations with the highest rates of lightning-caused damage reports per million people from 1959-1994 in *Storm Data*.

Rank	State	Damage reports/ million people/year
1	South Dakota	17.77
2	Kansas	14.17
3	Nebraska	11.36
4	Idaho	10.17
5	Vermont	8.79
6	Oklahoma	8.30
7	Arkansas	7.67
8	Wyoming	7.35
9	South Carolina	6.88
10	New Hampshire	6.78

TABLE 20. Ten US locations with the lowest rates of lightning-caused damage reports per million people from 1959-1994 in *Storm Data*.

Rank	State	Damage reports/ million people/year
43	Illinois	1.04
44	Arizona	0.99
45	District of Columbia	0.56
46	Hawaii	0.45
47	Nevada	0.44
48	Washington	0.41
49	New Jersey	0.38
50	Alaska	0.23
51	California	0.07
52	Puerto Rico	0.05

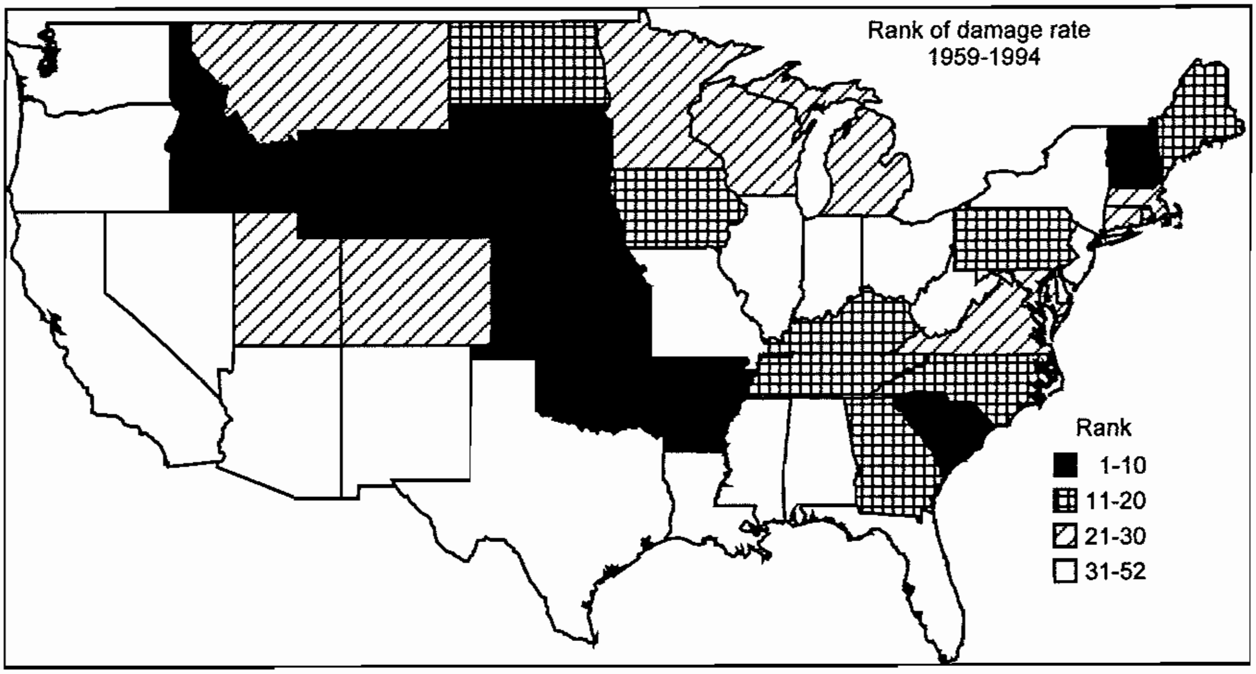

FIGURE 15. US map of rates of lightning damage reports ranked by state from 1959 to 1994.

E. SUMMARY

Table 21 lists the rates of fatalities, injuries, casualties, and damage reports, and corresponding ranks for the dataset. Information in this table was used to develop the preceding maps and tables.

Wyoming and New Mexico led the nation in rates of lightning-caused deaths, injuries, and casualties. However, Wyoming had almost all of its casualties in the 1960s and 1970s (section 5). States with high rates of casualties (Figures 11 to 14) were as follows:

- Rockies – high rates of casualties but less populous (Arizona, Colorado, Idaho, New Mexico, Montana, Utah, Wyoming).
- Plains – high rates of casualties, and average to less than average populations (Iowa, Kansas, Nebraska, Oklahoma, South Dakota).
- Southeast and adjacent states – moderate to high rates of casualties and average state populations (Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee).
- Northeast – moderate to high rates of casualties and less populous (Maine, New Hampshire, Vermont).
- Florida – very high rate of casualties and very populous.

The highest rates of damage reports were in a swath on the plains from North Dakota to Oklahoma. The pattern of damage report rates in many locations was not especially meaningful, since some states have exceptionally high or low ratios of reports to casualties for unknown reasons. For example, New Mexico had a low damage rate while it was second in casualty rates. Puerto Rico, California, and Alaska had very low rates of damage reports.

TABLE 21. Average population, and rate/million people/year of lightning-caused fatalities, injuries, casualties (fatalities and injuries combined), and damage reports for all states, the District of Columbia, and Puerto Rico from 1959 to 1994. Population is average of decennial census values from 1960 to 1990.

State	Average population [1000s]	Fatality rate Rate	Fatality rate Rank	Injury rate Rate	Injury rate Rank	Casualty rate Rate	Casualty rate Rank	Damage rate Rate	Damage rate Rank
Alabama	3,660	0.64	24	1.60	23	2.23	22	2.18	34
Alaska	369	0	52	0	52	0	52	0.23	50
Arizona	2,364	0.69	19	1.23	30	1.93	26	0.99	44
Arkansas	2,086	1.46	3	3.26	4	4.73	4	7.67	7
California	22,275	0.03	49	0.07	51	0.10	50	0.07	51
Colorado	2,536	1.04	6	3.24	5	4.28	5	3.42	21
Connecticut	2,990	0.12	45	0.70	42	0.82	44	2.50	29
Delaware	564	0.74	17	1.33	27	2.07	24	4.09	17
District of Columbia	691	0.20	44	0.89	37	0.92	41	0.56	45
Florida	8,605	1.10	4	3.80	3	4.91	3	1.45	40
Georgia	5,119	0.44	28	1.79	17	2.23	23	3.56	19
Hawaii	869	0	51	0.10	49	0.10	51	0.45	46
Idaho	833	0.67	22	2.23	13	2.90	13	10.17	4
Illinois	11,011	0.21	42	0.69	43	0.91	43	1.04	43
Indiana	5,223	0.39	29	0.87	38	1.26	37	1.86	35
Iowa	2,818	0.64	23	1.60	24	2.24	21	5.71	13
Kansas	2,317	0.67	20	2.13	15	2.80	14	14.17	2
Kentucky	3,401	0.67	21	1.63	21	2.30	20	4.62	16
Louisiana	3,830	0.83	9	1.65	19	2.48	17	2.28	32
Maine	1,078	0.57	25	2.68	6	3.25	8	6.52	11
Maryland	4,005	0.80	12	0.94	36	1.74	29	3.16	23
Massachusetts	5,648	0.12	47	1.63	22	1.75	28	2.97	25
Michigan	8,813	0.28	37	2.03	16	2.31	19	2.57	28
Minnesota	3,918	0.38	30	0.84	39	1.21	38	2.88	26
Mississippi	2,372	1.04	5	2.42	7	3.47	6	2.40	30
Missouri	4,758	0.46	27	0.54	44	1.00	40	1.48	38
Montana	739	0.75	15	1.65	20	2.41	18	3.31	22
Nebraska	1,511	0.75	16	1.27	28	2.02	25	11.36	3
Nevada	694	0.24	40	0.52	45	0.76	45	0.44	47
New Hampshire	844	0.26	38	2.24	12	2.50	16	6.78	10
New Jersey	7,082	0.22	41	0.49	46	0.71	46	0.38	49
New Mexico	1,200	1.88	1	3.89	2	5.76	2	1.25	41
New York	17,642	0.20	43	0.71	41	0.91	42	1.58	37
North Carolina	5,535	0.84	8	2.32	10	3.16	10	4.82	15
North Dakota	635	0.48	26	1.05	34	1.53	31	6.34	12
Ohio	10,501	0.30	34	1.13	32	1.44	35	1.09	42
Oklahoma	2,764	0.88	7	2.42	8	3.31	7	8.30	6
Oregon	2,334	0.08	48	0.23	48	0.31	48	1.79	36
Pennsylvania	11,715	0.26	39	1.26	29	1.52	32	3.42	20
Puerto Rico	2,296	0.36	31	0.07	50	0.44	47	0.05	52
Rhode Island	939	0.12	46	1.33	25	1.45	34	3.61	18
South Carolina	2,895	0.78	13	2.22	14	2.99	12	6.88	9
South Dakota	683	0.81	10	2.40	9	3.21	9	17.77	1
Tennessee	4,240	0.81	11	2.29	11	3.09	11	5.01	14
Texas	12,998	0.35	32	0.71	40	1.06	39	1.47	39
Utah	1,283	0.74	18	1.78	18	2.51	15	2.32	31
Vermont	477	0.76	14	1.05	35	1.80	27	8.79	5
Virginia	5,037	0.28	36	1.06	33	1.35	36	2.69	27
Washington	3,815	0.02	50	0.27	47	0.29	49	0.41	48
West Virginia	1,837	0.30	33	1.33	26	1.63	30	2.21	33
Wisconsin	4,492	0.28	35	1.21	31	1.49	33	3.15	24
Wyoming	397	1.47	2	5.74	1	7.21	1	7.35	8
United States	216,738	0.41		1.26		1.67		2.54	

5. YEAR-TO-YEAR VARIATIONS

A. NATIONAL BY YEAR

The number of lightning victims by year from 1959 to 1994 is shown in Figure 16. Only during one year, 1963, were there more deaths (210) than injuries (209). While the number of deaths have decreased, the number of injuries has increased during the period, as shown by the ratio of injuries to deaths in Figure 17.

When the growth in population is taken into account during this period, the trends can be separated into the following factors considered in more detail by López and Holle (1995, 1996):

- A 30% linear reduction in the rate of casualties per population during the period is attributed to improved forecasts and warnings, better awareness of the lightning threat, better quality of buildings available for shelter, and/or other socioeconomic changes.
- An additional 40% reduction in the rate of deaths per population may be due to improved emergency communications and medical care, such as cardiopulmonary resuscitation (CPR).
- The rate of injuries per population has decreased by only 8% because of the transfer of what may have become deaths into injuries due to better medical attention and other factors.
- Additional fluctuations on the scale of one or two decades broadly parallel national-scale changes in frequencies of thunderstorm days, cyclones, and surface temperatures (López and Holle, 1996).

Other long-term series of lightning-caused deaths include a decrease in the rate of deaths per million people from 1922 to 1979 in Singapore (Pakiam et al., 1981). A greater decrease was found in England and Wales from 1852 to 1990 (Elsom, 1993). In Australia, Coates et al. (1993) found an increase in the absolute number of deaths from 1824 to 1918, then a decrease through 1991; however the fatality rate per 100,000 people decreased through the record. When the state of Colorado was considered by López et al. (1995), no steady trend in the number of casualties was apparent from 1950 to 1991.

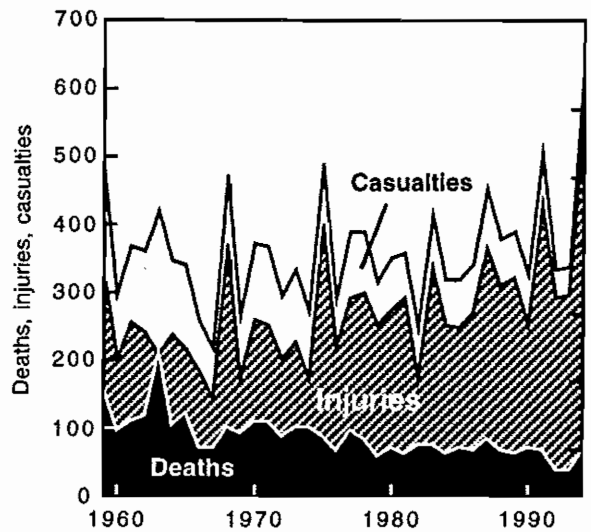

FIGURE 16. Number of lightning deaths, injuries, and casualties (deaths and injuries) by year from 1959 to 1994 for the US.

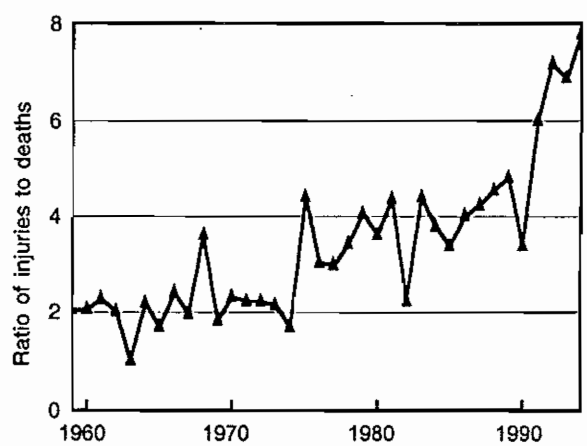

FIGURE 17. Ratio of the number of lightning injuries to deaths by year from 1959 to 1994 for the US.

Figure 18 shows the annual numbers of damage reports through the entire period of record. Holle et al. (1996) showed that *Storm Data* damages due to lightning are vastly underreported. Even though so many events are missed, the sample appears to indicate a systematic increase through time that could be due to the increase in population.

There is a substantial number of lightning victims and damages every year. Lightning entries have the least year-to-year variability of all convective-weather causes in Table 1, and less variability than nearly all other phenomena in Table 2. For example, some years have no hurricane deaths, and tornado casualties vary widely among years due to individual storm events. But the vulnerability to lightning is a constant and widespread threat to people and property during every thunderstorm season.

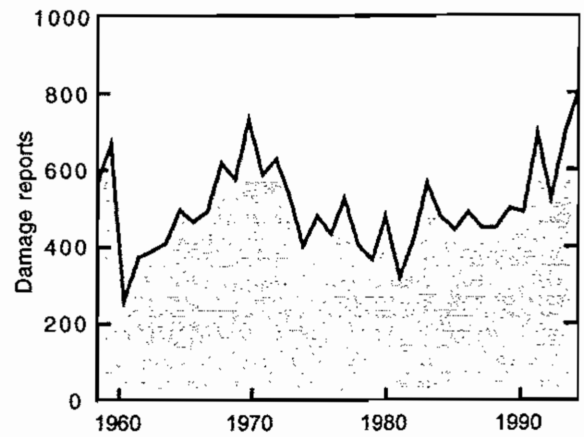

FIGURE 18. Number of lightning damage reports by year from 1959 to 1994 for the US.

B. NATIONAL BY DECADE

Time series by decade of reported frequencies of casualties and damages for the US are in Figure 19, and population-weighted time series are in Figure 20. Entries for the 1990s were made comparable to other decades by doubling the number of frequencies reported from 1990 to 1994. There was one large event due to an aircraft crash in 1963 (Maryland, 81 deaths).

Reported damage frequencies for the 1990s in Figure 19 are greater than during previous decades, while casualties are also somewhat more than in recent decades. Since only the first half of the 1990s has been included, it remains to be seen whether these trends will continue through the rest of the decade.

Population-weighted casualties by decade in Figure 20 show a decrease until the 1990s, when the rate increases again. The damage report rate also was decreasing until it increased sharply in the 1990s. Again, the changes in trends are largest in the 1990s, which includes 1990 to 1994 in this analysis.

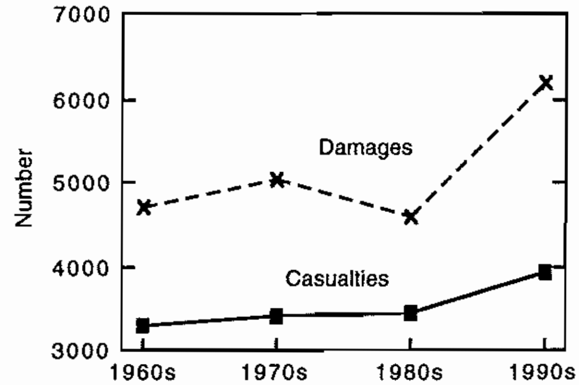

FIGURE 19. Number of reported US lightning casualties and damage reports by decade.

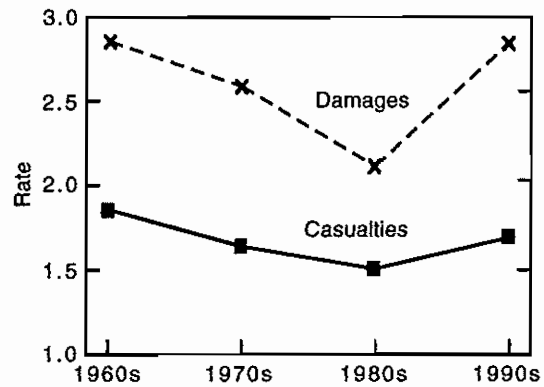

FIGURE 20. Population-weighted US lightning casualties and damage reports by decade.

C. REGIONAL BY DECADE

Eight regions of the United States were used for many of the subsequent analyses in this paper, as shown by Figure 21. The decadal trends in both casualties and damages are graphed for the eight regions in Figures 22 and 23.

Most regions have as many or more damage reports as casualties in both the actual and population-weighted time series. The only exceptions are in the southern Rockies and the southeast, where relatively few damages are reported.

Some general conclusions from reported frequencies in Figure 22 are the following:

- Casualties increased during the last two decades in the southeast, southern Rockies, and west coast states, but not elsewhere.
- Damage reports increased during the last two decades in all regions except in the west coast, midwest and northeast regions.

Population-weighted results in Figure 23 indicate that:

- Recent trends in casualties and damages for the west coast region are not as strong when population is taken into account as the actual reports indicated.
- Weighting by population made no difference in the other six regions.

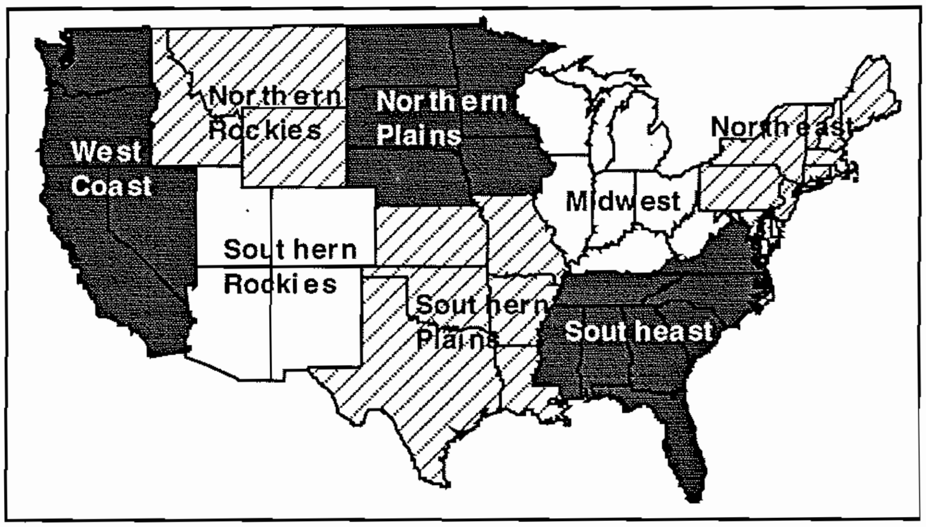

FIGURE 21. US regions for analysis of *Storm Data* entries.

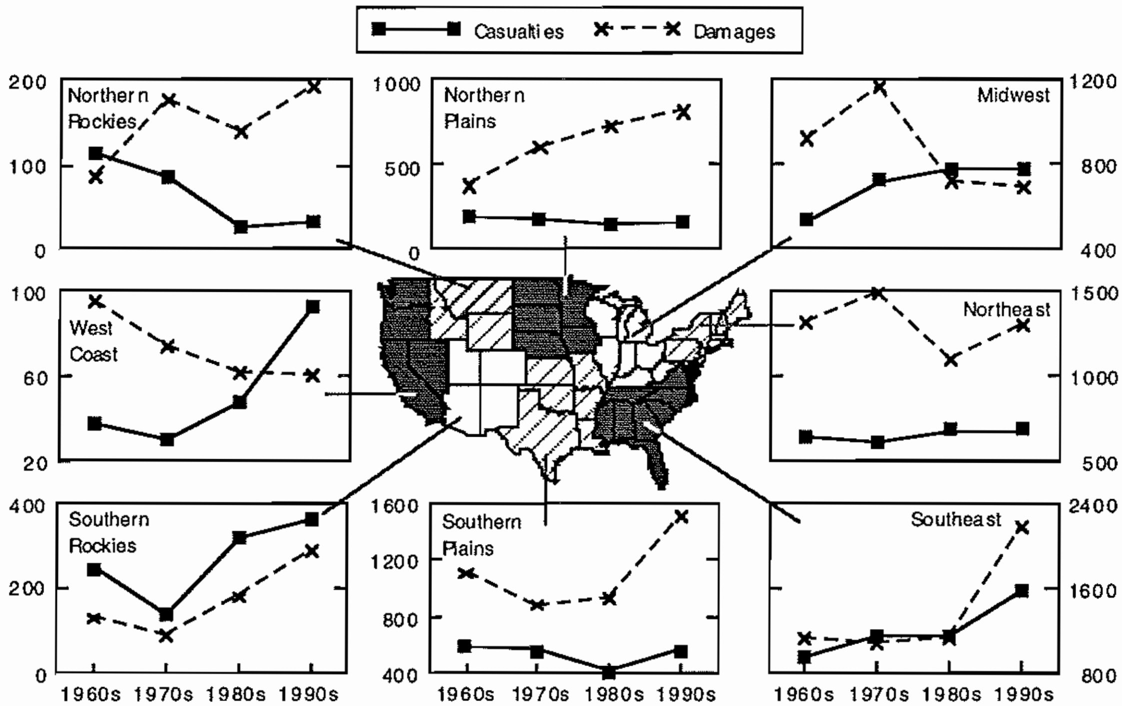

FIGURE 22. Decadal variations of number of reported lightning casualties (solid line with square) and damages (dashed line with x) by region of the US.

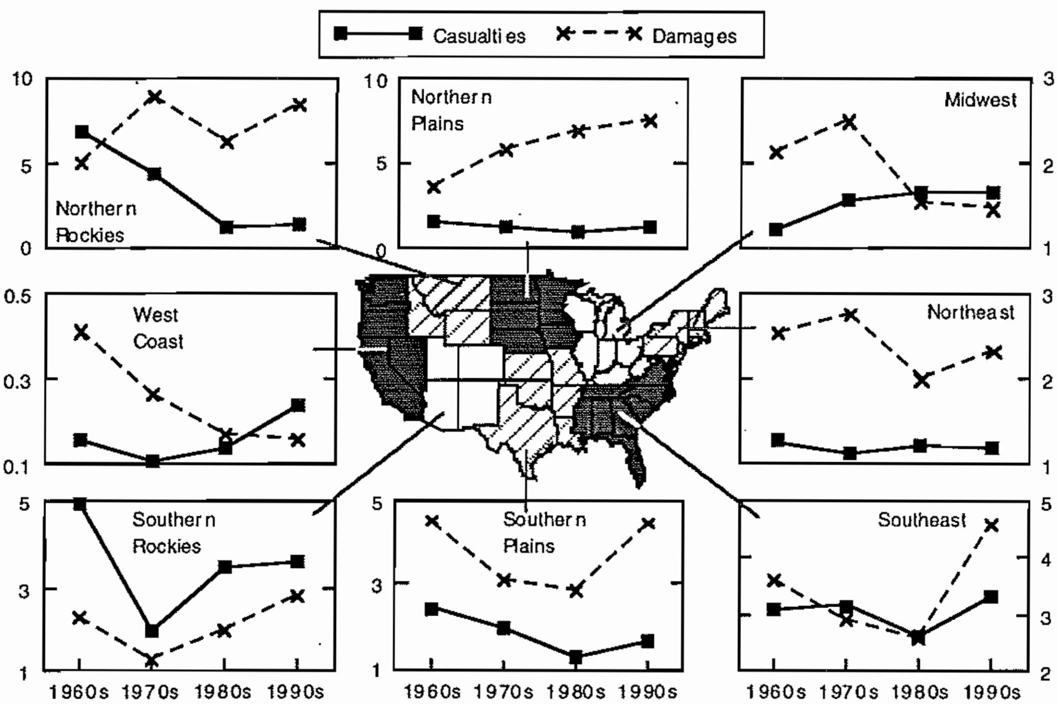

FIGURE 23. Decadal variations of lightning casualties per million people per year (solid line with square) and damages per million people per year (dashed line with x) by region of the US.

D. STATES BY DECADE

Another way to show changes through the decades is to plot reported frequencies for each state by decade, as shown in Figures 24 and 25, and Tables 22 and 23. Before weighting by population, casualties for the entire 36-year period were shown by state in Figures 1, 2, and 3, and damage reports in Figures 8 and 9. Decadal maps in Figure 24 and data in Table 22 for reported frequencies show the following:

Casualties

- Florida, Michigan, and Pennsylvania are always in the top ten.
- Highest numbers tend to be in the southeast US and most populous eastern states.
- There is a shift towards the southwest US with time.
- Most other states stay within one group of ten from the previous decade.

Damage reports

- Pennsylvania is always in the top ten.
- Highest numbers tend to be in the plains and most populous eastern states.
- States sometimes change by two groups of ten from the previous decade.
- These variations in damage reports do not necessarily represent actual changes in damages. For example, Georgia increased from 83 reports in the 1960s to 321 from 1990 to 1994, while Mississippi decreased from 58 in the 1960s to six reports in the 1990s.
- Table 22 shows more of these large variations in damage reports.

After weighting by population, casualty rates for the entire 36-year period were shown by state in Figures 11 and 12, and the damage rates in Figure 15. Decadal maps of the rates in Figure 25 and data in Table 23 show:

Casualty rate

- New Mexico and Arkansas are always in the top ten.
- Highest casualty rates are most consistent in the Rocky Mountain and southeastern states.
- Wyoming drops from a very high rate in the 1960s to a very low rate in the 1990s.

Damage rate

- Nebraska and Oklahoma are always in the top ten.
- Highest rates tend to be in the northern plains, southeast, and northeast states.
- Idaho maintains a high to very high rate during all decades.
- However, as noted earlier, there are variations in damage reports through time that are not likely to represent actual changes in damages, as shown in Table 23.

In summary, the decadal maps of numbers and population-weighted rates of casualties and damages show broad agreement with the maps for the 36-year *Storm Data* record. However, there are fairly large variations among decades in casualties and their rates, and very large variations in damages and their rates.

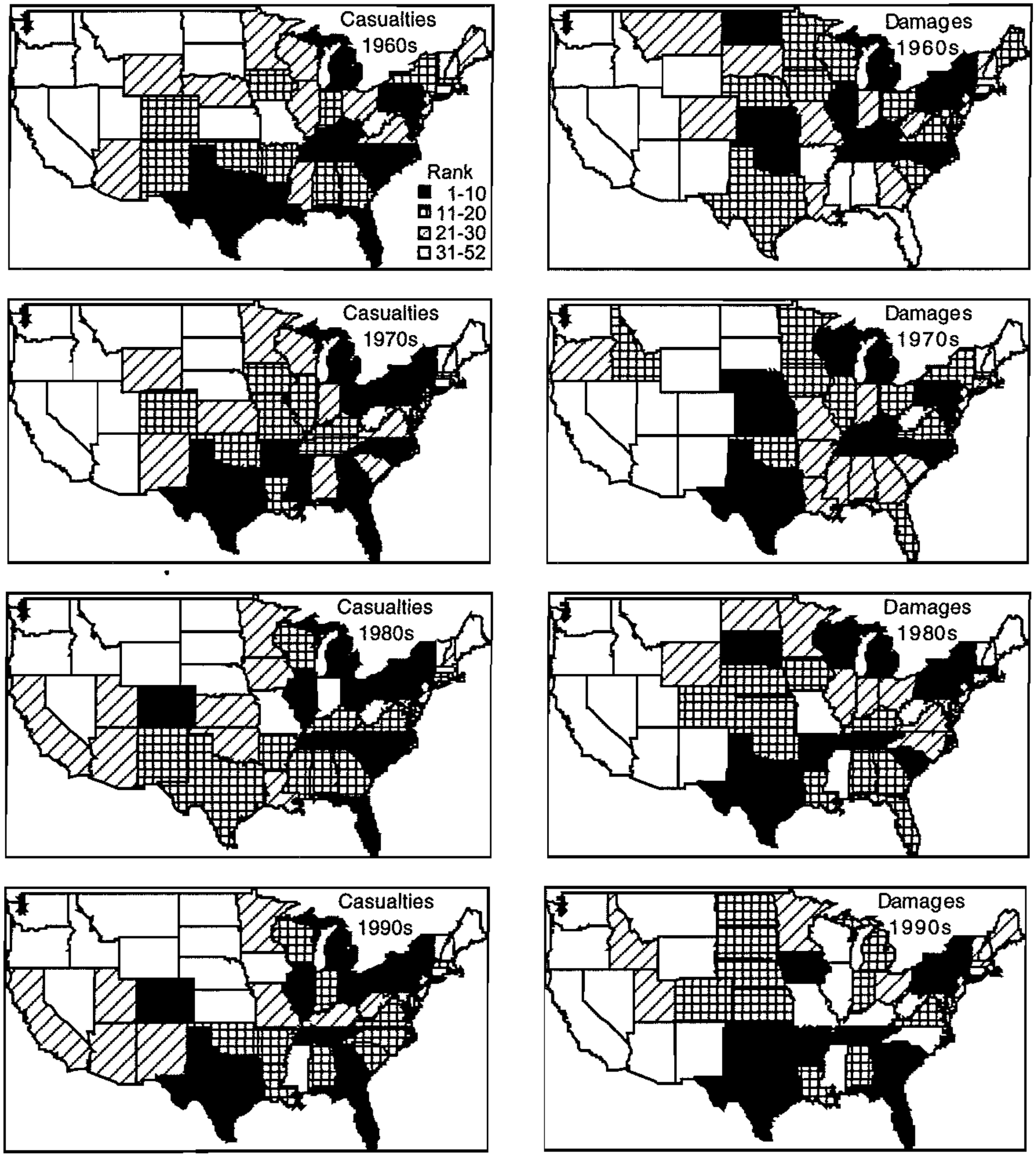

FIGURE 24. Decadal variations of lightning casualties and damages by state.

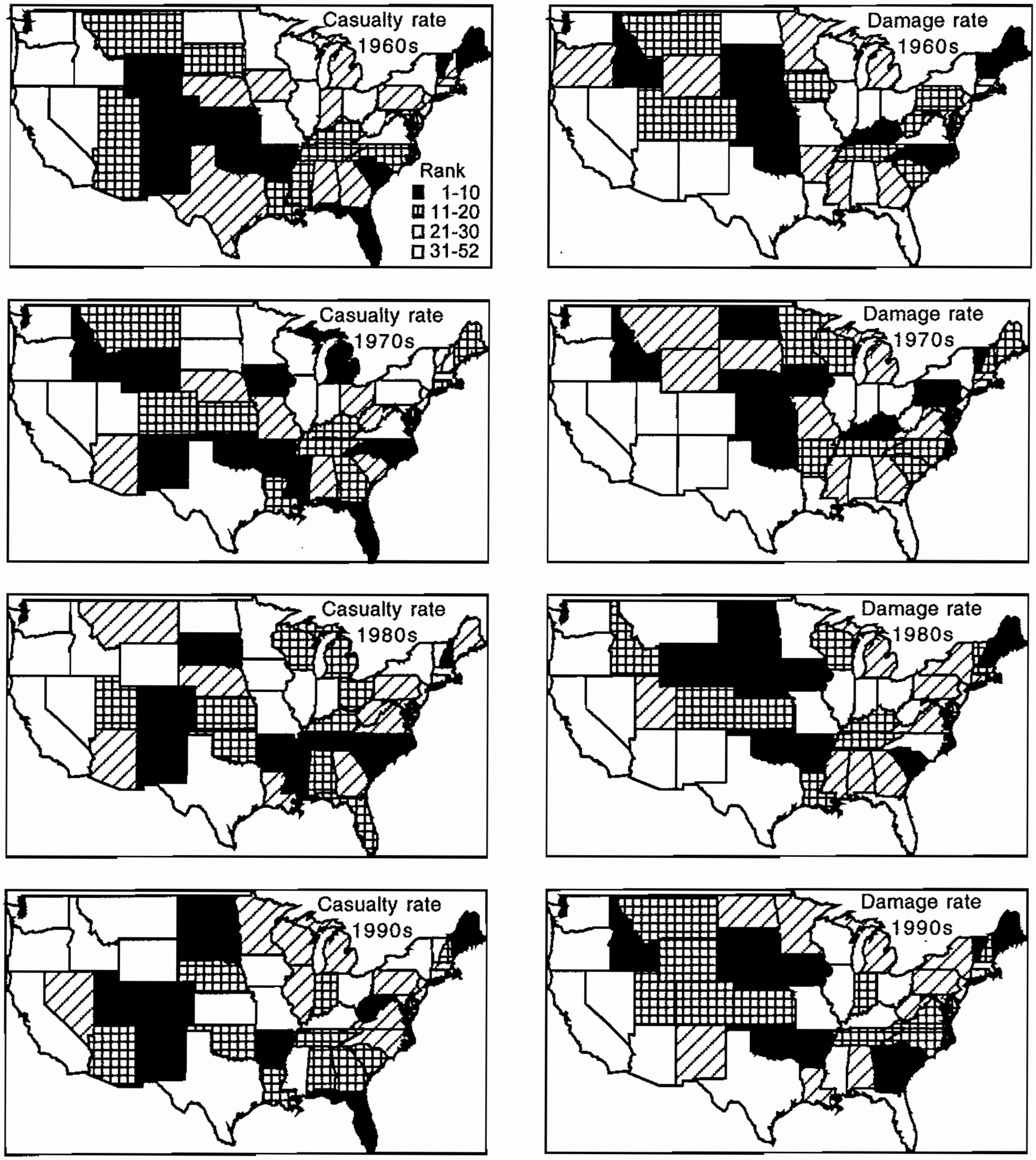

FIGURE 25. Decadal variations of the rates of lightning casualties and damages by state.

TABLE 22. Number of casualties and damage reports by decade for all states, D. C., and Puerto Rico during the decades of 1960s, 1970s, 1980s, and first half of the 1990s.

State	Casualties				Damage reports			
	1960s	1970s	1980s	1990-94	1960s	1970s	1980s	1990-94
Alabama	77	56	86	60	54	64	105	59
Alaska	0	0	0	0	0	1	1	1
Arizona	52	34	41	34	16	25	34	9
Arkansas	79	128	84	60	50	76	311	131
California	20	5	33	20	32	7	6	12
Colorado	85	60	141	91	63	42	113	83
Connecticut	13	29	25	11	70	75	79	28
Delaware	4	15	18	5	28	43	8	2
District of Columbia	3	6	1	12	2	7	1	3
Florida	278	484	322	412	46	141	131	129
Georgia	104	113	108	80	83	117	127	321
Hawaii	0	0	1	3	6	5	2	1
Idaho	38	32	9	6	44	148	52	59
Illinois	49	108	109	87	149	172	64	23
Indiana	82	52	28	60	77	98	67	98
Iowa	78	98	32	11	92	153	160	168
Kansas	95	41	64	13	580	268	110	75
Kentucky	108	63	77	20	180	265	102	17
Louisiana	136	100	65	45	62	63	117	70
Maine	51	26	19	23	91	48	64	45
Maryland	115	44	62	24	105	197	74	55
Massachusetts	104	101	74	39	166	174	178	57
Michigan	148	277	200	74	242	241	182	114
Minnesota	39	44	49	32	103	165	70	55
Mississippi	70	132	79	13	58	79	61	6
Missouri	39	74	25	27	87	117	17	25
Montana	21	16	12	8	32	18	12	25
Nebraska	38	26	23	19	95	224	146	95
Nevada	1	4	4	9	2	3	6	0
New Hampshire	14	14	37	11	60	40	64	33
New Jersey	34	79	23	27	24	23	3	36
New Mexico	77	45	97	26	12	15	6	21
New York	90	164	212	75	232	175	388	198
North Carolina	169	179	197	61	480	209	82	119
North Dakota	5	6	8	11	11	36	87	9
Ohio	77	160	241	66	112	163	98	37
Oklahoma	106	101	66	42	223	143	168	280
Oregon	7	12	5	1	47	51	34	7
Pennsylvania	195	130	179	112	426	642	192	154
Puerto Rico	11	5	13	2	0	2	2	0
Rhode Island	12	8	25	1	31	40	38	10
South Carolina	108	45	109	37	98	124	287	194
South Dakota	26	2	31	11	73	20	262	73
Tennessee	107	113	155	78	210	177	247	128
Texas	150	115	107	99	106	202	202	172
Utah	36	3	44	31	36	9	29	30
Vermont	18	7	3	2	74	27	15	33
Virginia	50	48	95	42	98	160	101	124
Washington	9	9	6	16	14	13	15	11
West Virginia	15	25	31	35	67	31	23	25
Wisconsin	55	39	93	46	90	191	187	30
Wyoming	56	38	5	2	10	10	74	11

TABLE 23. Decadal variations of casualties and damage reports/million people/year for all states, D. C., and Puerto Rico during the 1960s, 1970s, 1980s, and first half of the 1990s.

State	Casualty rate 1960s	Casualty rate 1970s	Casualty rate 1980s	Casualty rate 1990-94	Damage report rate 1960s	Damage report rate 1970s	Damage report rate 1980s	Damage report rate 1990-94
Alabama	2.3	1.5	2.2	3.0	1.6	1.7	2.6	2.9
Alaska	0	0	0	0	0	0.3	0.2	0.4
Arizona	3.4	1.5	1.3	2.1	1.0	1.1	1.1	0.5
Arkansas	4.3	6.1	3.6	5.1	2.7	3.6	13.4	11.1
California	0.1	0	0.1	0.1	0.2	0	0	0.1
Colorado	4.3	2.4	4.6	5.5	3.2	1.6	3.7	5.0
Connecticut	0.5	0.9	0.8	0.7	2.5	2.4	2.5	1.7
Delaware	0.8	2.6	2.9	1.5	5.6	7.5	1.3	0.6
District of Columbia	0.4	0.9	0.2	4.0	0.3	1.0	0.2	1.0
Florida	4.7	5.9	2.8	6.4	0.8	1.7	1.2	1.0
Georgia	2.4	2.2	1.8	2.5	1.9	2.3	2.1	9.9
Hawaii	0	0	0.1	0.5	0.9	0.6	0.2	0.2
Idaho	5.5	3.9	0.9	1.2	6.4	17.9	5.3	11.7
Illinois	0.5	1.0	1.0	1.5	1.4	1.5	0.6	0.4
Indiana	1.7	1.0	0.5	2.2	1.6	1.8	1.2	3.5
Iowa	2.8	3.4	1.1	0.8	3.3	5.3	5.6	12.1
Kansas	4.3	1.8	2.6	1.0	26.2	11.6	4.5	6.1
Kentucky	3.5	1.8	2.1	1.1	5.8	7.7	2.8	0.9
Louisiana	3.9	2.5	1.5	2.1	1.8	1.6	2.8	3.3
Maine	5.2	2.5	1.6	3.7	9.3	4.5	5.4	7.3
Maryland	3.3	1.1	1.4	1.0	3.0	4.8	1.6	2.3
Massachusetts	1.9	1.8	1.3	1.3	3.1	3.0	3.0	1.9
Michigan	1.8	3.1	2.2	1.6	2.9	2.7	2.0	2.5
Minnesota	1.1	1.1	1.2	1.5	2.9	4.2	1.7	2.5
Mississippi	3.2	5.6	3.1	1.0	2.6	3.3	2.4	0.5
Missouri	0.9	1.5	0.5	1.1	1.9	2.4	0.4	1.0
Montana	3.1	2.2	1.5	1.1	4.7	2.4	1.5	6.3
Nebraska	2.6	1.7	1.5	2.0	6.6	14.7	9.3	12.0
Nevada	0.3	0.6	0.4	1.5	0.5	0.5	0.6	0
New Hampshire	2.1	1.7	3.6	2.0	8.9	4.8	6.3	5.9
New Jersey	0.5	1.1	0.3	0.7	0.4	0.3	0	0.9
New Mexico	7.8	3.9	6.9	3.4	1.2	1.3	0.4	2.8
New York	0.5	0.9	1.2	0.8	1.3	1.0	2.2	2.2
North Carolina	3.5	3.3	3.2	1.8	10.0	3.8	1.3	3.6
North Dakota	0.8	0.9	1.2	3.4	1.8	5.7	13.5	2.8
Ohio	0.8	1.5	2.2	1.2	1.1	1.5	0.9	0.7
Oklahoma	4.3	3.6	2.1	2.7	9.1	5.1	5.4	17.8
Oregon	0.4	0.5	0.2	0.1	2.4	2.2	1.2	0.5
Pennsylvania	1.7	1.1	1.5	1.9	3.7	5.1	1.6	2.6
Puerto Rico	0.4	0.2	0.4	0.1	0	0.1	0.1	0
Rhode Island	1.3	0.8	2.6	0.2	3.4	4.2	3.9	2.0
South Carolina	4.3	1.6	3.3	2.1	3.9	4.3	8.7	11.1
South Dakota	3.9	0.3	4.5	3.2	10.8	2.9	37.8	20.9
Tennessee	2.9	2.7	3.3	3.2	5.6	4.2	5.2	5.2
Texas	1.4	0.9	0.7	1.2	1.0	1.6	1.3	2.0
Utah	3.7	0.2	2.8	3.6	3.7	0.7	1.8	3.5
Vermont	4.3	1.5	0.6	0.7	17.7	5.7	2.8	11.7
Virginia	1.2	1.0	1.6	1.4	2.3	3.2	1.8	4.0
Washington	0.3	0.2	1.3	0.6	0.4	0.3	0.3	0.2
West Virginia	0.8	1.4	1.7	3.9	3.7	1.7	1.2	2.8
Wisconsin	1.3	0.9	1.9	1.9	2.2	4.2	3.9	1.2
Wyoming	16.9	9.5	1.1	0.9	3.0	2.5	16.0	4.9

6. MONTHLY AND SEASONAL VARIATIONS

A. NATIONAL BY MONTH

Lightning casualties and damages peak during the summer months. July has the most deaths, injuries, casualties and damage reports, as shown in Figures 23 and Table 24. Monthly percentages increase gradually through the spring, when the thunderstorm season begins for most of the country. Deaths, injuries, and damages decline more rapidly in the fall compared to the slower increase in spring. Deaths occur earlier in the year somewhat more often than injuries (Figure 26). The Maryland aircraft crash in 1963 (mentioned in section 5B) killed 81 people in December and accounts for the large number of deaths in that month.

Differences between the percentages of casualties and damages are in the lower part of Figure 26. Casualties reach a sharper maximum in July, while damage reports are spread somewhat more evenly through the year. The more concentrated casualty distribution may occur because people are exposed to lightning more often during the midsummer months. In contrast, immovable property and other objects are damaged relatively more often before and after the summer months. If this is true, damage reports may be a better representation of the distribution of cloud-to-ground flashes than casualties.

For the US, all of the following papers show a July maximum, as well as a slower increase before that month compared to the decrease after July:

* *Storm Data* deaths from 1959 to 1965 (Zegel, 1967).
* *Storm Data* deaths and injuries from 1968 to 1976 (Mogil et al., 1977).
* *Storm Data* casualties from 1968 to 1985 (Duclos and Sanderson, 1990).
* *Storm Data* casualties from 1959 to 1990 (López and Holle, 1995).
* Cloud-to-ground flashes from 1992 to 1995 (Orville and Silver, 1997).

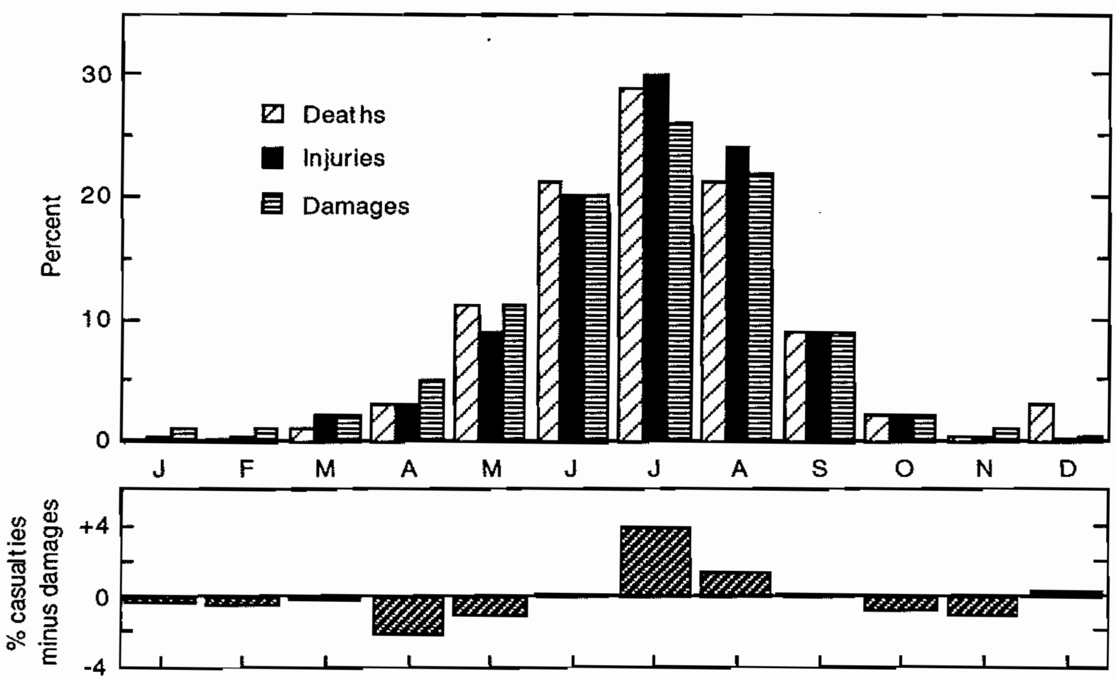

FIGURE 26. Top: Monthly variations of lightning fatalities, injuries, and damage reports for the US from 1959 to 1994. Bottom: Percent casualties minus damage reports by month.

Within the US, most of the following papers show the same July peak and a slower rise before July than the subsequent decrease:

-Florida, 1978 to 1987

Fatalities peaked in August (Duclos et al., 1990).

-Michigan, 1959 to 1987

Storm Data deaths (Ferrett and Ojala, 1992).

-Central Florida, 1983 to 1990

Fatalities and property damages peaked in August, while injuries were most common in July (Holle et al., 1992).

-Colorado, 1950 to 1991

A few more casualties in July than June. Casualties were more clustered during midsummer in Colorado than for the US in Figure 26 (López et al., 1995).

-Colorado, Utah, and Wyoming, 1987 to 1991

Slightly more insurance claims were made in August than July (Holle et al., 1996).

Outside the United States, the following two published monthly distributions show very different results from the typical US monthly distributions:

*Singapore, 1922 to 1979

Two maxima, in November and April, were found in fatalities. Since this location is at 1°N, the midsummer concept is not relevant. The annual cycle of deaths was identified as similar to that of local thunderstorms (Pakiam et al., 1981).

*Australia, 1824 to 1991

The largest number of fatalities are in January, which had a slightly larger number of deaths than in December. Taking into account the reversal of seasons in the Southern Hemisphere, this is the same result as found in the US. One difference from the US data in Figure 26 is that the buildup to midsummer is somewhat faster than the dropoff (Coates et al., 1993).

TABLE 24. Monthly totals of number and percentage of annual total of deaths, injuries, casualties, and damage reports due to lightning in the United States from 1959 through 1994.

Month	Deaths		Injuries		Casualties		Damage reports	
	Number	%	Number	%	Number	%	Number	%
January	5	0.2	28	0.3	33	0.3	102	0.5
February	6	0.2	29	0.3	35	0.3	150	0.8
March	40	1	158	2	198	2	425	2
April	97	3	288	3	385	3	996	5
May	347	11	910	9	1257	10	2169	11
June	690	21	1970	20	2660	20	3935	20
July	934	29	2960	30	3894	30	5155	26
August	687	21	2345	24	3032	23	4280	22
September	281	9	869	9	1150	9	1755	9
October	51	2	202	2	253	2	514	3
November	16	0.5	45	0.5	61	0.5	242	1
December	85	3	14	0.1	99	0.8	92	0.5
	3239		9818		13,057		19,815	

B. REGIONAL BY MONTH

Monthly distributions of casualties and damage reports by region of the country are shown in Figures 27 and 28. Most regions show damage reports to be spread somewhat more widely through the year than casualties. Casualties and damages in the northern regions of the country tend to have narrower distributions centered on summer than regions in the southern US due to a shorter thunderstorm season in colder regions. The broadest monthly distributions are in the Southern Plains.

Figure 27 shows the differences between monthly percentage frequencies in the Northern Rockies, Northern Plains, Midwest, and Northeast, and percent frequencies in the Southern Rockies, Southern Plains, and Southeast. Northern regions have up to 4% more casualties and damages in midsummer, while southern regions have more cases in spring and, to a lesser extent, in autumn.

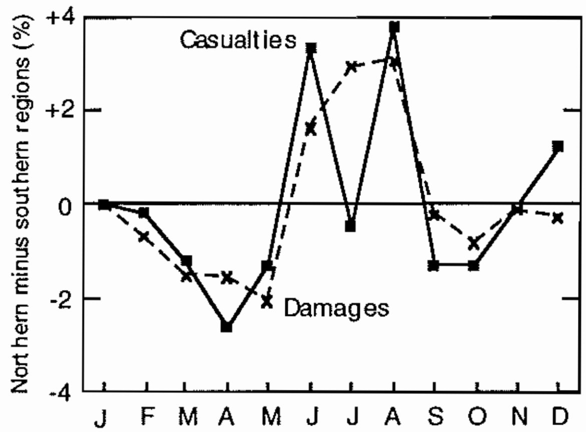

FIGURE 27. Differences between monthly percentages of lightning casualties (solid line) and damage reports (dashed) in northern minus southern regions of the US.

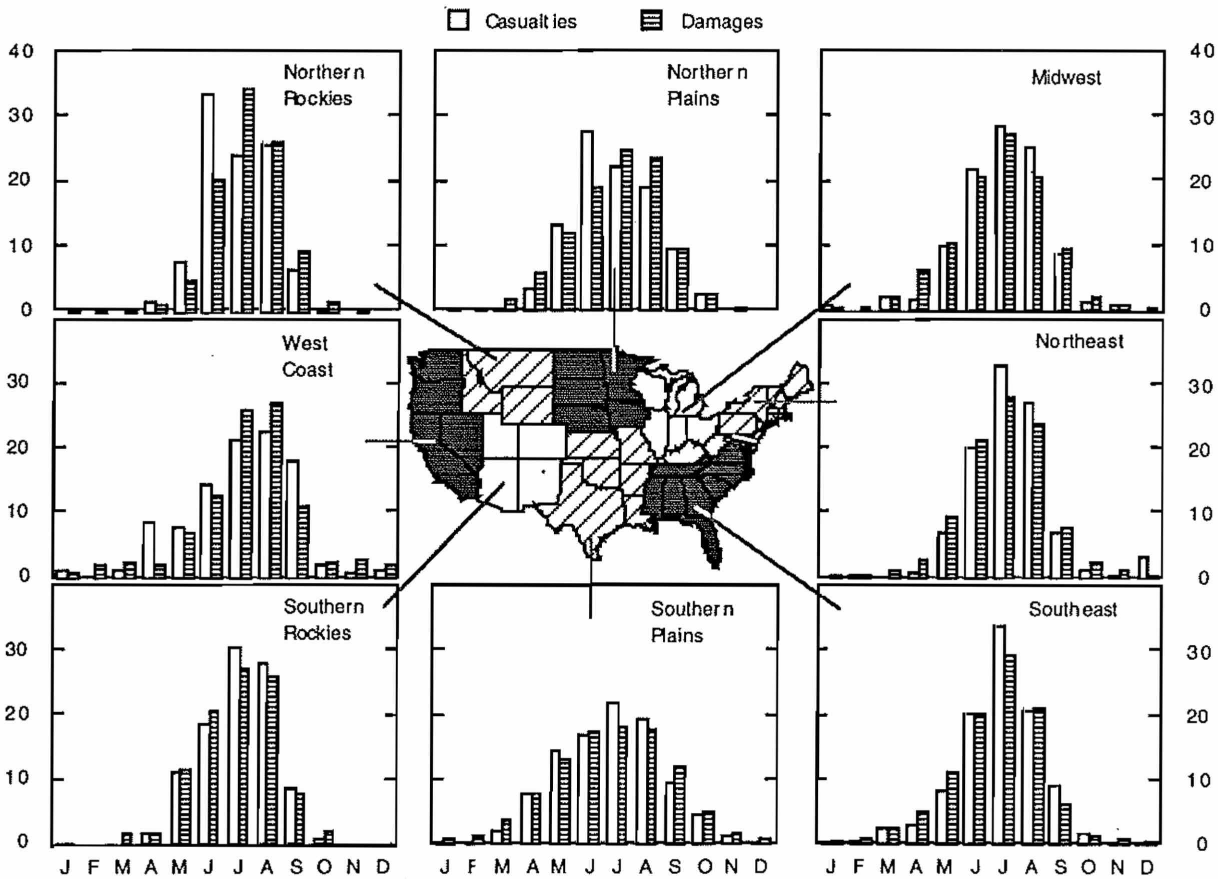

FIGURE 28. Monthly variations of lightning casualties and damage reports by region of the US (%).

C. NATIONAL BY SEASON

Seasonal totals of casualties and damages reports are listed in Table 25. Maps of these two categories are also given by state in Figure 29 based on Table 26.

Spring (March, April, May)

Casualties in spring show a similar distribution to the annual pattern in Figure 2 with one exception. The higher annual ranks in the Northeast are much lower, most likely due to less lightning during these spring months than elsewhere.

Damage reports show a similar distribution to the whole year in Figure 9, except for the same reduction in the Northeast shown by casualties.

Summer (June, July, August)

Casualties in the summer are almost identical in distribution to the map for the entire year in Figure 2. This result is as expected, since Tables 25 and 26 show that most lightning casualties occur during summer.

Damage reports for the summer are also very similar to the whole-year results shown in Figure 9.

Autumn (September, October, November)

Casualties show a return to high rankings for states in the Southern Plains, as for spring. West Coast states rank relatively high in casualties during autumn, but rank very low when the entire year is considered.

Damage reports are distributed similarly in the autumn and spring.

TABLE 25. Seasonal totals of numbers of annual of casualties and damage reports due to lightning in the United States from 1959 through 1994.

Season	Casualties	Damage reports
Spring	1840	3590
Summer	9586	13,369
Autumn	1464	2511
Winter	167	344

Winter (December, January, February)

Casualties occurred in only 21 states during winter. The highest concentration is in the Southern Plains, as shown by monthly distributions in Figure 28. West-coast states continue to rank relatively high in casualties, as in autumn. The largest number of deaths was in Maryland (81) due to the December 1963 aircraft crash (sections 5B and 6A).

Damage reports are most common in the Southern Plains, but are scarce in states to the north. California and Hawaii are ranked among the top 30 states, while they rank very low in summer.

In summary, summer maps of casualties and damage reports closely follow the annual maps. During other seasons, lightning cases are more frequent in the southern regions of the United States. Frequencies in the northeast are low except during the summer, while they are high in the West Coast states during autumn and winter.

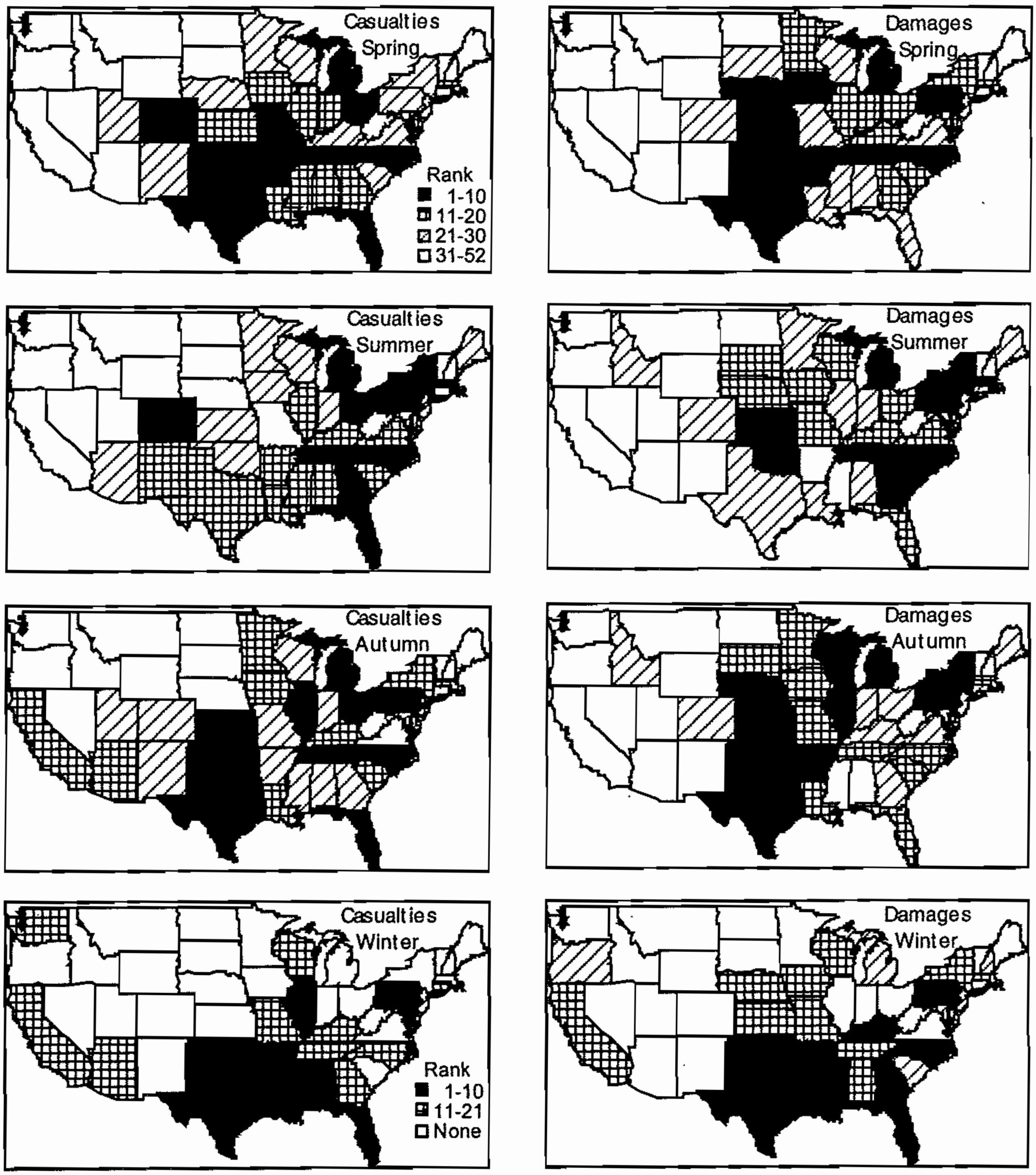

FIGURE 29. Seasonal variations of lightning casualties and damage reports by state.

TABLE 26. Number of casualties and damage reports by season for all states, D. C., and Puerto Rico.

State	Casualties				Damage reports			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Alabama	39	234	15	7	56	197	23	11
Alaska	0	0	0	0	1	1	1	0
Arizona	10	114	38	2	4	70	9	1
Arkansas	83	245	20	7	149	297	102	28
California	15	39	22	3	14	18	21	7
Colorado	58	318	18	0	54	230	28	0
Connecticut	10	68	10	0	44	181	41	3
Delaware	11	29	2	0	5	64	10	4
District of Columbia	11	11	1	0	3	11	0	0
Florida	134	1090	286	13	55	314	64	17
Georgia	50	345	14	1	96	499	44	17
Hawaii	1	3	0	0	3	1	7	3
Idaho	9	72	6	0	22	241	40	2
Illinois	42	248	58	12	89	246	77	0
Indiana	43	181	14	0	82	234	32	2
Iowa	49	150	28	0	144	361	68	6
Kansas	49	140	45	0	216	726	230	10
Kentucky	37	217	23	1	104	412	36	14
Louisiana	49	260	34	4	74	172	55	14
Maine	4	118	4	0	26	193	32	2
Maryland	41	114	14	81	79	341	31	4
Massachusetts	40	281	33	1	105	417	71	10
Michigan	62	606	64	0	139	557	114	4
Minnesota	21	123	25	0	95	256	54	1
Mississippi	42	228	21	5	68	105	20	12
Missouri	66	89	20	1	71	123	52	7
Montana	8	53	3	0	7	70	10	1
Nebraska	24	76	11	0	129	399	83	7
Nevada	4	12	2	0	3	7	1	0
New Hampshire	2	72	2	0	29	155	18	4
New Jersey	9	154	22	0	10	82	2	4
New Mexico	36	198	15	0	8	39	6	1
New York	30	509	38	0	108	758	130	9
North Carolina	119	464	43	3	197	682	65	16
North Dakota	2	29	4	0	10	119	16	0
Ohio	111	347	87	0	86	295	29	2
Oklahoma	81	172	71	7	197	447	152	30
Oregon	5	12	9	0	9	123	14	4
Pennsylvania	32	540	64	8	182	1077	172	15
Puerto Rico	0	24	12	0	0	2	2	0
Rhode Island	2	39	6	2	25	72	20	5
South Carolina	36	238	32	0	116	533	62	6
South Dakota	10	60	9	0	49	334	53	1
Tennessee	107	318	46	2	178	501	73	12
Texas	149	231	114	4	239	284	135	31
Utah	16	82	18	0	19	70	17	1
Vermont	0	30	0	0	18	117	14	2
Virginia	30	194	11	0	77	347	43	0
Washington	5	33	1	1	7	37	10	2
West Virginia	8	97	3	0	27	109	8	2
Wisconsin	31	190	18	2	60	332	107	10
Wyoming	7	89	8	0	2	96	7	0
Total	1840	9586	1464	167	3590	13,369	2511	344

7. TIME OF DAY VARIATIONS

A. NATIONAL

The time of day when casualties and damages due to lightning were reported in the US shows a strong dominance of afternoon reports (Figure 30 and Table 27). Two-thirds of the casualties occur between noon and 6 p.m. Local Standard Time (LST). Casualties show a steady increase toward a maximum at 1600 LST, followed by a slightly slower decrease after the maximum. Therefore, most of the lightning-vulnerable activities engaged by people occur during the day.

However, damage reports are more broadly distributed through the 24-hour day. They show a steeper increase toward a maximum at 1700 LST than the decline after the maximum toward midnight. There is another slight increase in damages reports between one and two hours after midnight.

Differences between the two time series are in lower Figure 30. During the afternoon, there are up to 6% more casualties than damage reports. But at night, some hours have more than 3% less casualties than damage reports.

The difference at night is apparently due to the immobile nature of buildings and other objects. In contrast, people are less prone to be involved in lightning-sensitive activities at night, and also tend to avoid brightly-illuminated nighttime storms. There is a type of nocturnal thunderstorm complex, the mesoscale convective system, that occurs over the plains states during the summer, and produces tremendous amounts of lightning. These mesoscale convective systems, sometimes covering areas the size of Iowa, can produce rates over 3000 ground strikes per hour (Goodman and MacGorman, 1986; Holle et al., 1995).

Table 27 shows the numbers that were used to construct Figure 30. Not all *Storm Data* entries have times reported. Of the 13,057 casualties in Table 3, Table 27 shows that 8681 (66%) have times, while 61% of the damage reports have times associated with the report.

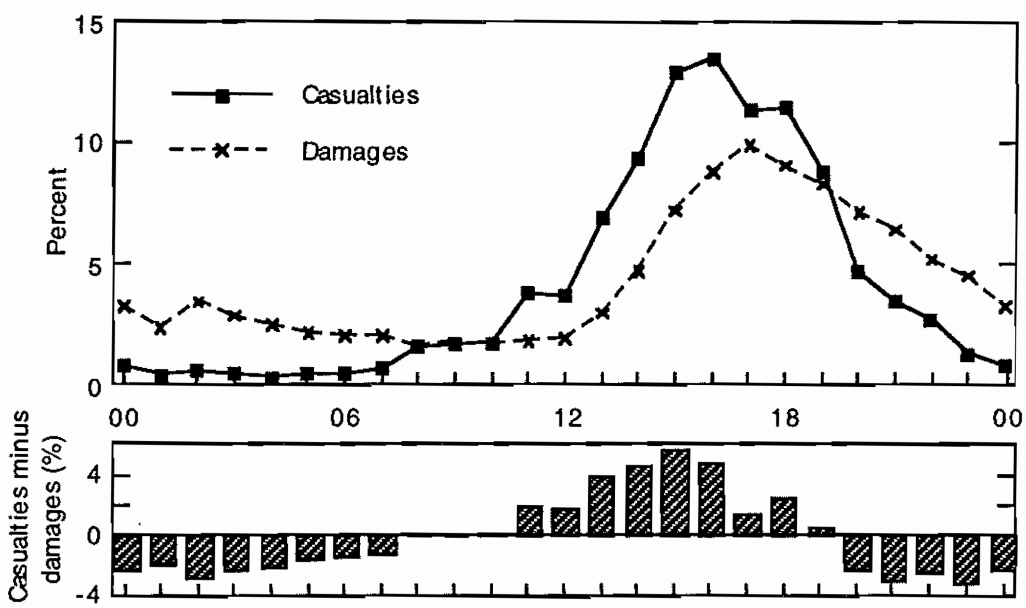

FIGURE 30. Top: Time of day of lightning casualty and damage reports for the United States from 1959 to 1994. Bottom: Percent casualties minus percent damage reports by hour. Time label for end of hour.

Maximum lightning impacts during the afternoon have been widely documented. For a small dataset from 1968 to 1985, deaths in North Carolina peaked at 1800 LST (Duclos and Sanderson, 1990). However, the most common maxima are from 1400 to 1600 LST:

- Deaths in Singapore from 1922 to 1979 (Pakiam et al., 1981).
- Deaths in Florida from 1978 to 1987 (Duclos et al., 1990).
- Deaths, injuries, and damage reports in Michigan from 1959 to 1987 (Ferrett and Ojala, 1992).
- Casualties in the US from 1959 to 1990 (López and Holle, 1995).

On the time scale of individual storms, Holle et al. (1992) studied summer storms in central Florida. People had a tendency to be a casualty of lightning more often toward the start and end of thunderstorms, while objects on the ground were struck more uniformly through the lifetime of a storm. As on the daily scale, immobile objects were less sensitive to the storm than people who took actions against the threat.

TABLE 27. Time of day of numbers and percentages of deaths, injuries, and damage reports due to lightning in the United States from 1959 through 1994. LST is Local Standard Time.

	Deaths		Injuries		Casualties		Damage reports	
	Cases	%	Cases	%	Cases	%	Cases	%
0000-0059 LST	9	0.4	18	0.3	27	0.3	267	2.2
0100-0159	10	0.5	33	0.5	43	0.5	394	3.3
0200-0259	15	0.7	23	0.4	38	0.4	330	2.8
0300-0359	7	0.3	11	0.2	18	0.2	291	2.4
0400-0459	14	0.7	22	0.3	36	0.4	245	2.0
0500-0559	7	0.3	27	0.4	34	0.4	227	1.9
0600-0659	17	0.8	34	0.5	51	0.6	224	1.9
0700-0759	29	1.4	99	1.5	128	1.5	181	1.5
0800-0859	30	1.4	108	1.6	138	1.6	196	1.6
0900-0959	44	2.1	99	1.5	143	1.7	185	1.5
1000-1059	63	3.0	257	3.9	320	3.7	210	1.8
1100-1159	54	2.6	254	3.8	308	3.6	222	1.8
1200-1259	140	6.8	444	6.7	584	6.7	333	2.8
1300-1359	192	9.3	600	9.1	792	9.1	541	4.5
1400-1459	270	13.0	829	12.5	1099	12.7	841	7.0
1500-1559	296	14.3	854	12.9	1150	13.2	1024	8.5
1600-1659	263	12.7	702	10.6	965	11.1	1153	9.6
1700-1759	236	11.4	740	11.2	976	11.2	1061	8.8
1800-1859	158	7.6	589	8.9	747	8.6	973	8.1
1900-1959	85	4.1	312	4.7	397	4.6	833	7.0
2000-2059	51	2.5	244	3.7	295	3.4	755	6.3
2100-2159	38	1.8	182	2.8	220	2.5	607	5.1
2200-2259	29	1.4	79	1.2	108	1.2	525	4.4
2300-2359	13	0.6	51	0.8	64	0.7	371	3.1
	2070		6611		8681		11,989	

B. REGIONAL

The times of casualties and damage reports are shown by region in Figures 31 and 32. Highest frequencies of casualties are typically within one hour of 1500 LST. Only the west coast has a broad afternoon maximum from 1200 to 1900 LST for a small sample size (100 casualties). Damage reports usually peak an hour or two later than casualties (Figure 30). In the plains and midwest, there are many nighttime damage reports that may come from the nocturnal thunderstorms mentioned earlier.

Figure 31 shows differences between plains and midwest states, compared to the northeast, southeast, and Rockies. The main departures are in the afternoon, when the Rockies and eastern states have 13% more casualties and 8% more damages than on the plains and in the midwest. Relatively narrow distributions (leptokurtic) are apparent in the Rockies, southeast, and northeast, while plains and midwest time series are broader (platykurtic).

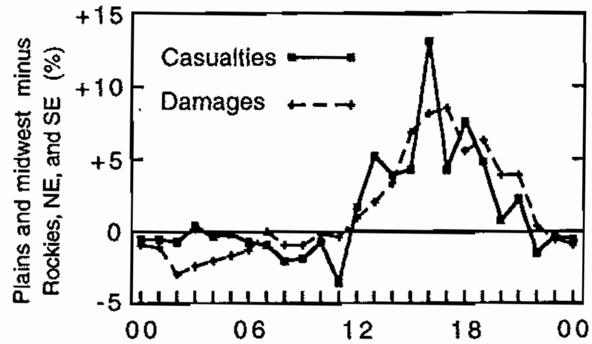

FIGURE 31. Differences between hourly percentages of lightning casualties (solid line) and damage reports (dashed) in plains and midwest regions minus Rockies, northeast, and southeast regions.

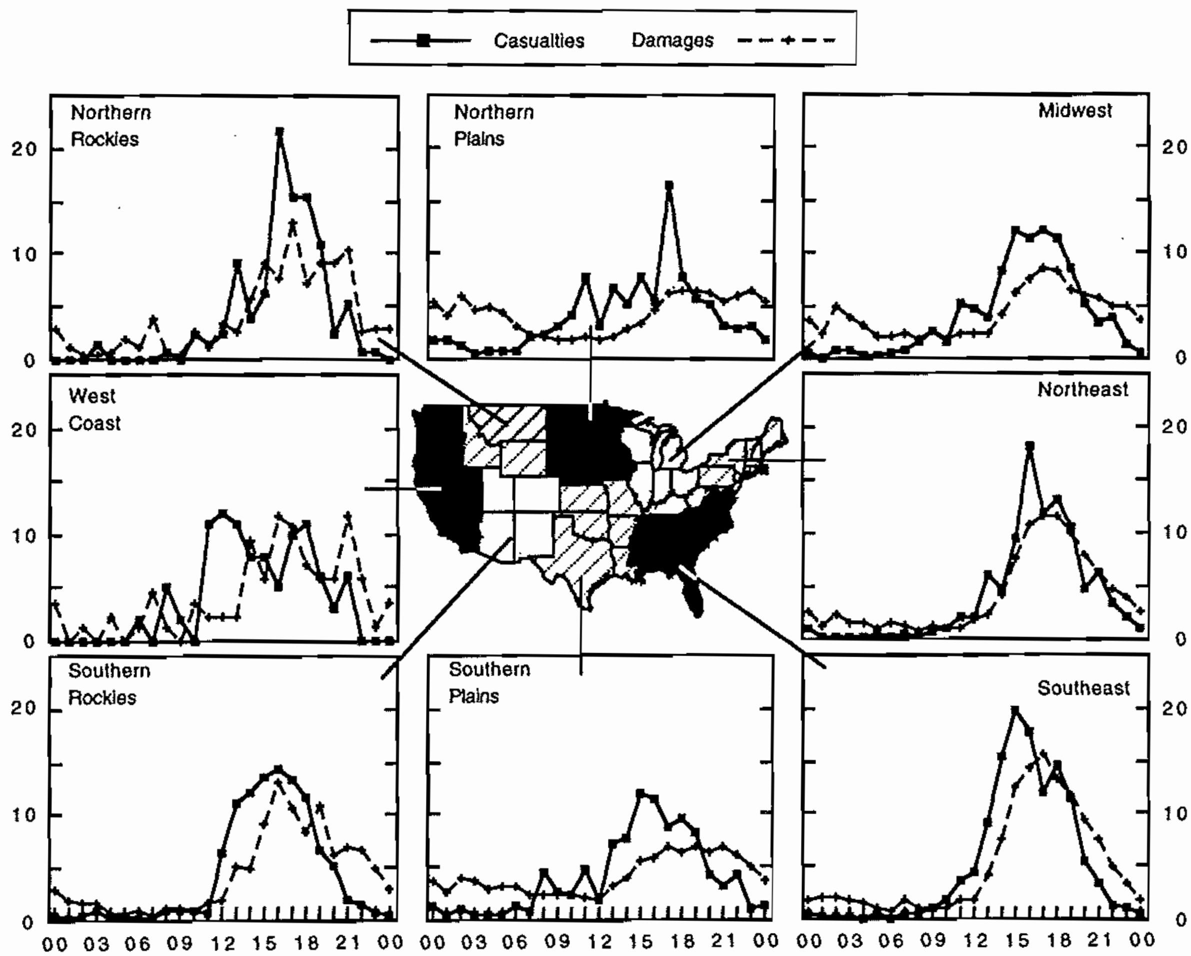

FIGURE 32. Time of day of lightning casualties (solid line) and damage reports (dashed) by region in %.

C. 6-HOUR PERIODS

Casualties and damage reports by 6-hour periods of the day are shown by maps in Figure 33. These results can be compared to Figure 2 for casualties and Figure 9 for damage reports during all hours.

Night (0000-0559 LST)

Casualties and **damage reports** during the nighttime are most frequent in the plains and upper midwest states, and a few populous eastern states. Compared to maps in Figures 2 and 9 for the entire sample, there is a shift in the highest-ranking states to the north and east from Texas, through Oklahoma and the plains states, to Wisconsin. Only the first 27 ranks of casualties are shown, since all states ranked lower than 27th have one or zero casualties. There were 62 deaths (3% of the day's fatalities with known times), 135 injuries (2%), and 1753 damage reports (15%) in *Storm Data* during these hours.

Of particular interest is how a lightning casualty can occur during these night to early morning hours. There were 29 deaths in 19 events between midnight and 0559 LST since 1980 in *Storm Data*. Of this total, 59% of the deaths and 58% of the events occurred when people were in a house set on fire by lightning. The next most common situation occurred when people were camping in tents (21% of the deaths and 16% of the events). Remaining incidents since 1980 involved a backpacker, an airman in an Air Force hangar, a driver losing control of his truck when it was struck by lightning while crossing a bridge, a night watchman at a factory, and people walking in a field.

Morning (0600-1159 LST)

Casualties during the morning are spread widely across the country. **Damage reports** are most common in the plains states in a similar pattern to the map for nighttime hours. There were 237 deaths (11%), 851 injuries (13%), and 1218 damage events (10%) in *Storm Data* during these morning hours.

Afternoon (1200-1759 LST)

Casualties during the afternoon resemble Figure 2 for the entire day. This result is to be expected since these are the most frequent hours for deaths and injuries. There were 1397 deaths (67%) and 4169 injuries (63%) in *Storm Data* during these hours. **Damage reports** are not as closely related to the 24-hour map in Figure 9, since the 4952 damage reports are only 41% of the *Storm Data* reports during these hours.

Evening (1800-2359 LST)

Casualties during the evening have the same shift in highest-ranking states to the north and east from Texas as noted for nighttime hours. **Damage reports** during the evening are similar to the whole-day map in Figure 9 and the afternoon map in Figure 30. There were 374 deaths (18%), 1457 injuries (22%), and 4064 damage reports (34%) in *Storm Data* during these hours.

Afternoon maps of both casualties and damage reports have the largest 6-hour sample sizes of the day and dominate Figures 2 and 9 for the whole day. There is a substantial number of high-ranking states for both categories in the southeast and eastern states. However, during other time periods, the maps show a tendency for events to occur away from the east and southeast, and greater activity on the plains and eastward to the midwest. Rasmusson (1971) found a similar pattern in the diurnal distribution of thunderstorms based on audible thunder reports.

Other studies have shown afternoon maxima in lightning impacts according to three- or six-hour periods:

* Deaths, injuries, and damage reports in central Florida from 1983 to 1990 (Holle et al., 1992).
* Fatalities in Australia from 1824 to 1991 (Coates et al., 1993).
* Casualties and damage reports in Colorado from 1950 to 1991 (López et al., 1995).

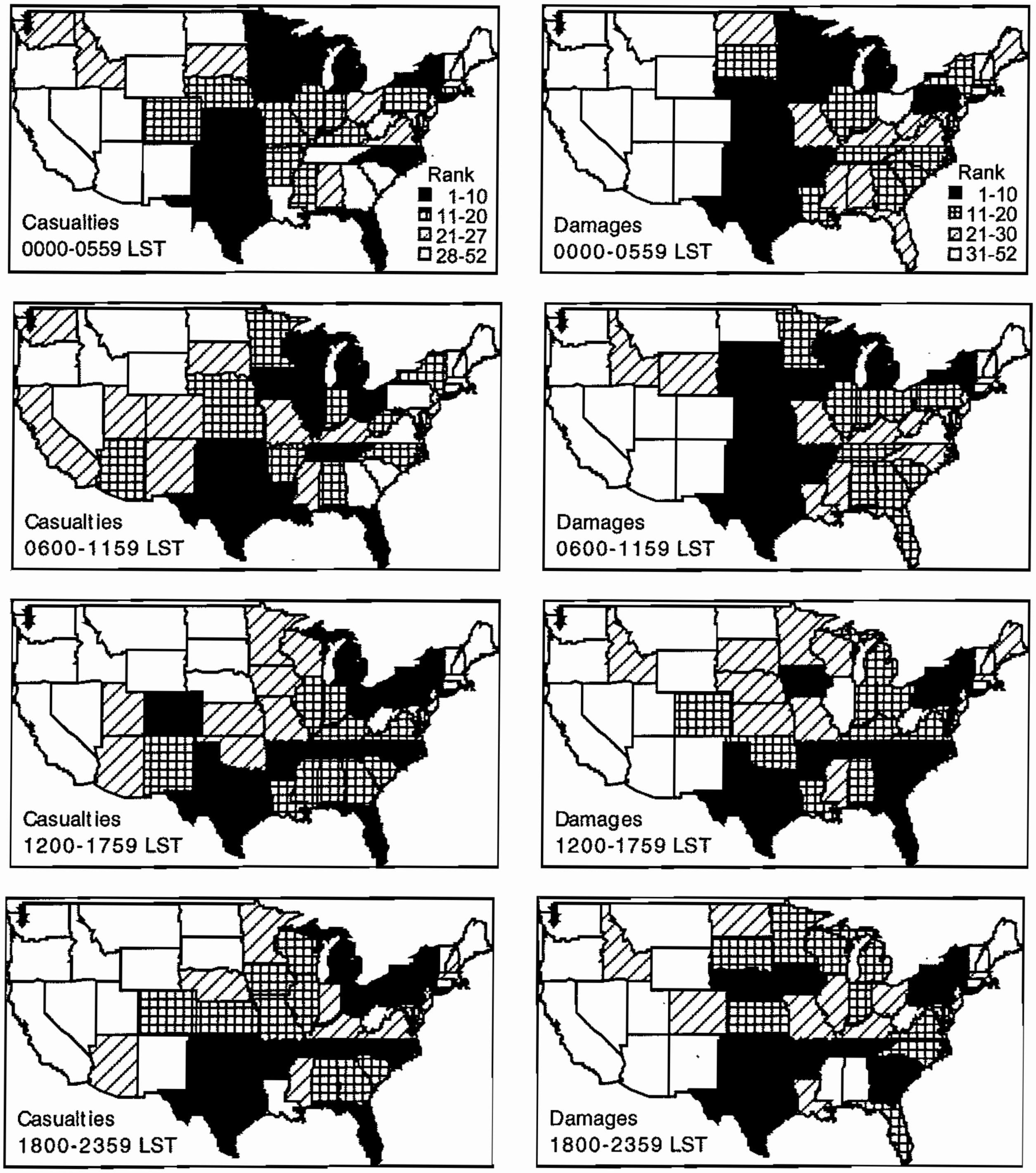

FIGURE 33. Rank of lightning casualties and damage reports by 6-hour periods and state of the US from 1959 to 1994.

D. SEASONS

Diurnal variations of lightning reports are subdivided by season in Figure 34 and Table 28. Seasonal variations were shown earlier in Figure 29, and Tables 25 and 26.

Spring (March, April, May)

Casualties in spring occur during the same afternoon hours as for the entire year and country in Figure 30. However, there is also a secondary peak before noon.

Damage reports show a weaker diurnal cycle than spring casualties in Figure 34, or all damages for the year in Figure 30. An equal number of reports occur from 1700 to 1900 LST, several hours later than casualties.

Summer (June, July, August)

Casualties and **damage reports** during the summer months closely follow the annual curves in Figure 30, since they comprise more than half of the year's sample (Table 28).

Autumn (September, October, November)

Casualties in autumn occur most often in a broad afternoon maximum, but there is also a secondary peak in the morning.

Damage reports are most common in late afternoon, but are spread across the hours in a similar manner to spring frequencies (Table 28). Damages lag casualties by several hours.

Winter (December, January, February)

Casualties in winter are erratic as shown by the highest number (15) at 0900 LST. There is a secondary peak during the more typical mid-afternoon hours. The sample has only 63 cases.

Damage reports are spread across the entire day and night and show no distinct maximum in time.

In summary, maps of casualties and damages during summer closely resemble the annual cycle. Maxima in casualties usually lead maxima in damages by two to three hours. In spring and autumn, the casualty maxima are less distinct than for summer, and damages are spread more uniformly through day and night. In winter, the afternoon peak is weak for casualties and disappears for damage reports.

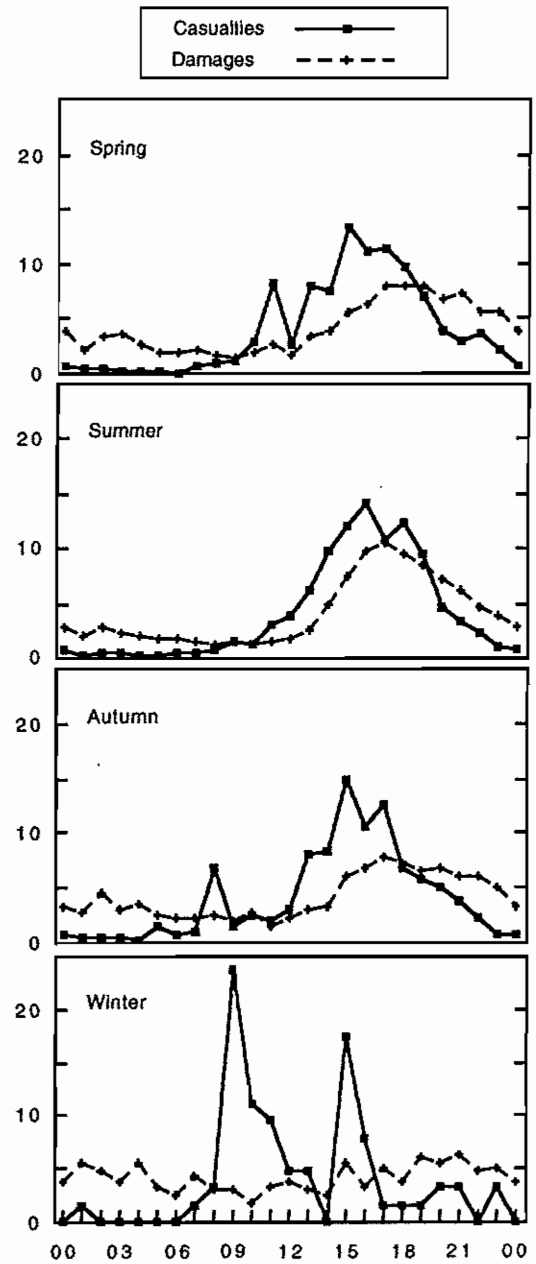

FIGURE 34. Time of day of lightning casualties and damages by season in the US from 1959 to 1994 (%).

TABLE 28. Seasonal variations in the time of day of casualties and damage reports (%) due to lightning in the United States from 1959 through 1994.

	Spring		Summer		Autumn		Winter	
Time	Casualties	Damages	Casualties	Damages	Casualties	Damages	Casualties	Damages
0000-0059 LST	0.4%	2.2	0.2	2.0	0.6	2.8	1.6	5.6
0100-0159	0.4	3.5	0.5	2.9	0.6	4.6	0	4.7
0200-0259	0.2	3.6	0.5	2.4	0.4	3.0	0	3.8
0300-0359	0.2	2.6	0.2	2.1	0.3	3.6	0	5.6
0400-0459	0.2	2.0	0.3	1.9	1.4	2.6	0	3.4
0500-0559	0	2.0	0.4	1.8	0.8	2.3	0	2.6
0600-0659	0.8	2.2	0.5	1.6	0.9	2.2	1.6	4.3
0700-0759	0.9	1.7	0.7	1.2	6.8	2.5	3.2	3.0
0800-0859	1.3	1.5	1.5	1.6	1.4	2.0	23.8	3.0
0900-0959	2.9	1.9	1.2	1.2	2.4	2.8	11.1	1.7
1000-1059	8.2	2.6	3.0	1.5	2.0	1.6	9.5	3.4
1100-1159	2.7	1.6	3.8	1.8	3.0	2.2	4.8	3.8
1200-1259	7.9	3.5	6.3	2.5	8.0	3.0	4.8	3.0
1300-1359	7.5	3.8	9.7	5.0	8.3	3.2	0	2.6
1400-1459	13.4	5.6	12.1	7.6	14.8	6.1	17.5	5.6
1500-1559	11.2	6.3	14.2	9.7	10.7	6.7	7.9	3.4
1600-1659	11.4	8.0	10.9	10.5	12.6	7.9	1.6	5.1
1700-1759	9.7	8.0	12.4	9.5	6.8	7.2	1.6	3.8
1800-1859	7.0	8.0	9.5	8.5	5.7	6.5	1.6	6.0
1900-1959	4.0	6.7	4.6	7.1	5.1	6.8	3.2	5.6
2000-2059	3.0	7.2	3.4	6.1	3.8	6.1	3.2	6.4
2100-2159	3.7	5.5	2.4	4.7	2.2	6.1	0	4.7
2200-2259	2.3	5.7	1.1	3.9	0.8	5.0	3.2	5.1
2300-2359	0.8	4.0	0.8	2.8	0.7	3.2	0	3.8
Number	1324	2248	6229	7989	1065	1517	63	234

8. DAY OF WEEK VARIATIONS

The distributions of deaths, injuries, casualties, and damage reports by day of week are shown in Figure 35 and Table 29.

Fatalities

Only Sunday has significantly more deaths than other days of the week. The Sunday total is 24% more than the daily average. A slight tendency for more deaths is also evident on Wednesday.

Injuries

The largest numbers of injuries are on Wednesday and the weekend days, and the least are on Tuesday and Friday.

Casualties

Casualties are most frequent on Sunday, then the next most common day is Saturday, followed by Wednesday. This total of deaths and injuries closely follows the injury curve, as can be expected since there are three times as many injuries as deaths.

Damage reports

Damage reports show the greatest frequency on Monday, then they decrease on nearly every day until reaching the lowest number on Saturday.

More casualties on weekends suggest that recreation is a factor on those days. An unpublished study for Colorado by the authors showed more recreational casualties on weekend days and holidays than on weekdays, while employment cases occurred more often on non-holiday week days. This type of study requires analysis of the verbal narratives in *Storm Data*, and was not made for this US dataset. The digitized *Storm Data* does not contain information on the activity being undertaken by people when they became lightning victims. More damage reports on weekdays is difficult to understand, but could result from variations in reporting by newspapers that do not publish every day.

TABLE 29. Day of week of lightning casualties and damages in the US from 1959 to 1994.

Day	Deaths	Injuries	Casualties	Damages
Sunday	574	1502	2076	3411
Monday	445	1428	1873	3983
Tuesday	429	1258	1687	3709
Wednesday	473	1483	1956	3769
Thursday	428	1350	1778	3668
Friday	422	1261	1683	3262
Saturday	467	1534	2001	3163

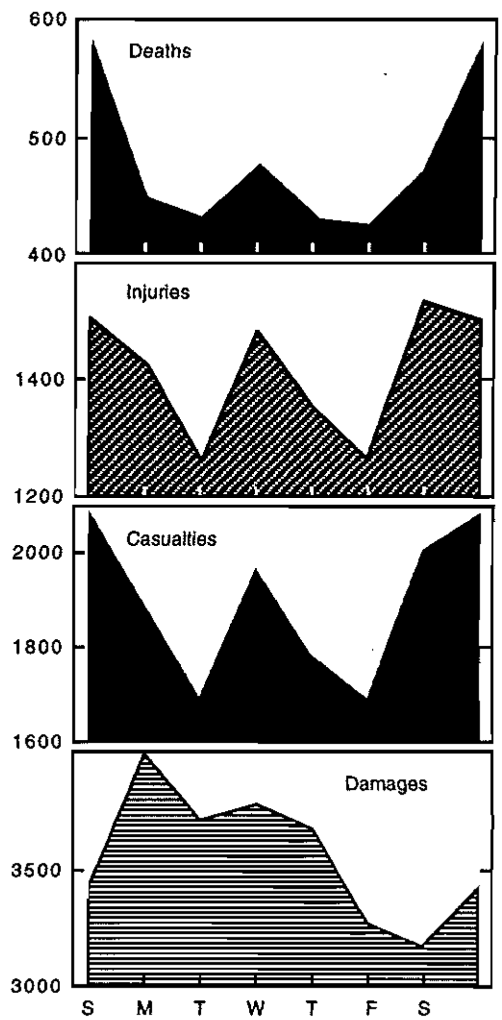

FIGURE 35. Day-of-week variations of US lightning deaths, injuries, casualties, and damages from 1959 to 1994.

9. NUMBER OF VICTIMS PER EVENT

The most common situation is for one lightning victim to be involved in an incident when at least one person was killed or injured. Tables 30 and 31 and Figure 36 show the number of people per event by category.

For incidents involving deaths only, 91% of the cases had one fatality. Another 8% of the events had two people killed in the same incident. One event had more than eight people killed (Figure 36 and Table 31) when 81 people were killed in a Maryland airliner crash in December 1963 (sections 5B and 6A).

For incidents involving injuries only, 68% of the cases had one injury, which is a lower rate than for deaths. The largest number of injuries involved 90 people at a campground in Michigan (section 3C) as reported by Ferrett and Ojala (1992).

The distributions of casualty events in the figure and both tables closely resemble the injury distributions.

The same tendency for single victims has been noted with other datasets:

- US, 1959 to 1965
  Of the fatalities, 70% occurred singly (Zegel, 1967).
- Singapore, 1922 to 1979
  One person was involved in 85% of the deaths (Pakiam et al., 1981).
- Australia, 1824 to 1991
  Of the deaths, 92% occurred singly (Coates et al., 1993).
- Colorado, 1950 to 1991
  Only one person was involved in 89% of the deaths, 70% of injuries, and 66% of the casualties (López et al., 1995).

In summary, lightning usually kills people one at a time, while there is more than one person involved in quite a few injury events. The dominance of single-person events shows the need for lightning safety education so that people take personal responsibility for their own threat from lightning.

TABLE 30. Short summary of deaths, injuries, and casualties in *Storm Data* incidents (%).

Victims	Deaths	Injuries	Casualties
1	90.9%	68.2	68.4
2	7.8	17.4	17.4
>2	1.4	14.4	14.1
Incidents	2834	5212	7181

TABLE 31. Number of deaths, injuries, and casualties in each *Storm Data* incident.

Victims	Deaths	Injuries	Casualties
One	2575	3553	4912
Two	220	908	1253
Three	22	306	445
Four	10	142	214
Five	2	90	103
Six	2	54	74
Seven	1	42	47
Eight	1	20	23
Nine	0	12	21
Ten	0	12	8
11-20	0	46	52
21-30	0	21	21
31-40	0	2	2
41-50	0	2	2
51-60	0	0	0
61-70	0	0	0
71-80	0	1	2
81-90	1	1	2
Incidents	2834	5212	7181

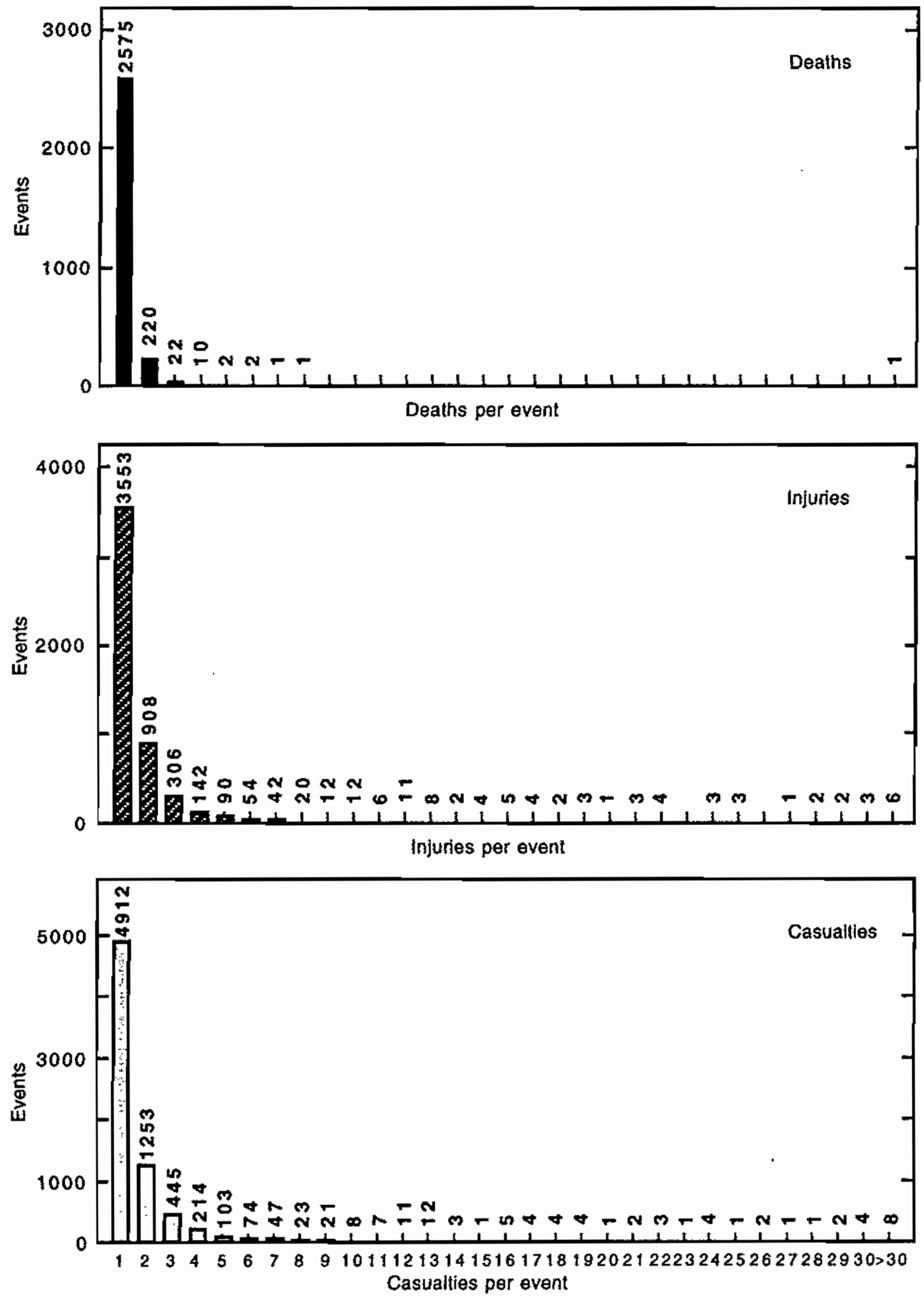

FIGURE 36. Number of US lightning deaths, injuries, and casualties per event from 1959 to 1994.

10. GENDER

Most lightning victims are male, as shown in Figures 37 and 38, and Tables 32 and 33. The results use the *Storm Data* categories in the digital database of male, female, both, or unknown. Cases classified as 'both' in the death category indicate that one male and one female were killed in the same event; these cases were split between male and female in the analyses. Similar definitions apply to injuries and casualties. For the entire US, 17.8% of the deaths do not have gender reported (Table 32). A larger number of injuries, 33.8%, do not specify gender, and 29.8% of casualties are unspecified. Since the unknown portions are large, and assuming no gender bias for unreported cases, results are shown with and without unknowns.

Including unknowns

Including unknown cases, deaths by gender is shown in Figure 37. Males are the most frequent lightning victims, but the unknown category is larger than the female group. Figure 37 is shown for deaths because the percentage of cases with no gender reported was much less for deaths than injuries. By region, when unknown cases are included, more than half of all deaths and injuries involved one or more males, except for injuries in the west coast, midwest, and northeast. Another 5 to 18% involved one or more females. The largest number of unknown cases was 46.1% in the northeast for injuries (Table 32).

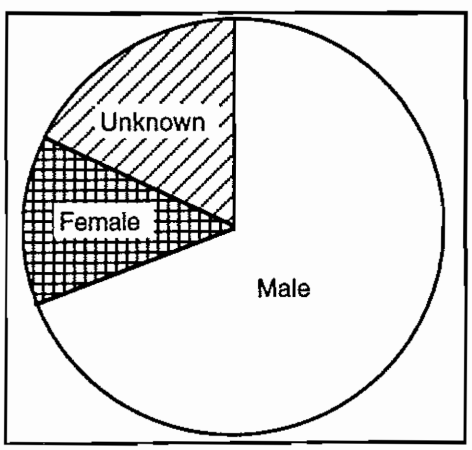

FIGURE 37. Gender of US lightning deaths from 1959 to 1994 including unknown cases.

Without unknowns

For the US without the unknown cases, Figure 38 shows that males are the most frequent lightning fatalities (84.1%) and injuries (82.3%). By region (Table 33), the male component ranged from 76.1 to 93.6% for deaths and injuries. The female range was 6.4 to 23.9% in the regions.

In summary, males are killed 4.6 times as often as females, and are 5.3 times as likely as females to be injured. There are twice as many injuries as deaths without a gender specified in the *Storm Data* digital dataset.

Males also comprised between 79 and 87% of the victims in the US (Duclos and Sanderson, 1990), Florida (Duclos et al., 1990; Holle et al., 1992), and North Carolina (Langley et al., 1991). Similar ratios were found in Singapore (Pakiam et al., 1981), and England and Wales (Elsom, 1993).

Many of the same studies showed that males in their twenties are the most frequent victims of lightning. The digital record in *Storm Data* does not include the victim's age but its verbal narrative usually does. For this reason, an age analysis of the entire *Storm Data* record was not made for the present report.

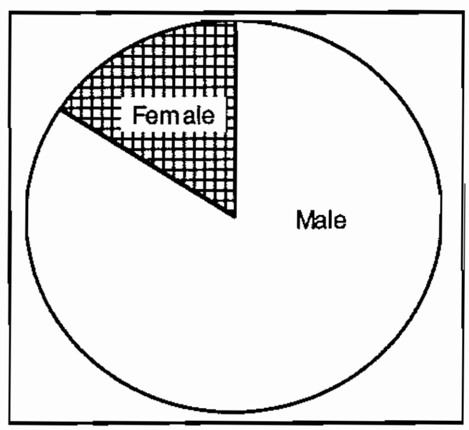

FIGURE 38. Gender of US lightning deaths from 1959 to 1994 without unknown cases.

TABLE 32. Gender of lightning deaths in the US and geographical regions from 1959 to 1994 (%) including unknown cases

Region	Male	Female	Unknown
West Coast			
Deaths	78.4%	5.4	16.2
Injuries	40.5	12.7	46.8
Casualties	49.1	11.0	39.9
Northern Rockies			
Deaths	86.9	6.6	6.6
Injuries	60.8	12.9	26.3
Casualties	67.1	11.4	21.6
Southern Rockies			
Deaths	69.1	17.8	13.0
Injuries	66.7	13.6	19.7
Casualties	67.4	14.8	17.8
Northern Plains			
Deaths	71.0	9.5	19.5
Injuries	58.0	10.7	31.3
Casualties	62.0	10.3	27.7
Southern Plains			
Deaths	75.0	16.2	8.8
Injuries	65.4	13.9	20.6
Casualties	68.5	14.6	16.9
Midwest			
Deaths	71.1	12.7	16.2
Injuries	50.0	10.6	39.4
Casualties	54.3	11.1	34.6
Northeast			
Deaths	58.1	9.6	32.3
Injuries	43.0	11.0	46.1
Casualties	46.1	10.7	43.2
Southeast			
Deaths	68.5	12.9	18.6
Injuries	56.9	11.6	31.5
Casualties	59.7	11.9	28.3
United States			
Deaths	69.1	13.1	17.8
Injuries	54.5	11.7	33.8
Casualties	58.1	12.1	29.8

TABLE 33. Gender of lightning deaths in the US and geographical regions from 1959 to 1994 (%) without unknown cases.

Region	Male	Female
West Coast		
Deaths	93.6%	6.4
Injuries	76.1	23.9
Casualties	81.6	18.4
Northern Rockies		
Deaths	93.0	7.0
Injuries	82.5	17.5
Casualties	85.5	14.5
Southern Rockies		
Deaths	79.5	20.5
Injuries	83.0	17.0
Casualties	82.0	18.0
Northern Plains		
Deaths	88.2	11.8
Injuries	84.5	15.5
Casualties	85.8	14.2
Southern Plains		
Deaths	82.3	17.7
Injuries	82.5	17.5
Casualties	82.4	17.6
Midwest		
Deaths	84.8	15.2
Injuries	82.4	17.6
Casualties	83.0	17.0
Northeast		
Deaths	85.8	14.2
Injuries	79.7	20.3
Casualties	81.2	18.8
Southeast		
Deaths	84.2	15.8
Injuries	83.0	17.0
Casualties	83.3	16.6
United States		
Deaths	84.1	15.9
Injuries	82.3	17.7
Casualties	82.8	17.2

11. LOCATION

The digital record of *Storm Data* divides the locations of lightning casualties into eight groups (Table 34), plus two unknown categories. Figure 39 shows the US results in graphical form. Comments on each category follow.

Not reported; various other and unknown locations

There are many unknown or unreported locations in the *Storm Data* record (40.4%) according to Table 34. Regional percentages of unknown casualties range from 27.5% in the Northern Rockies to 59.5% on the west coast. This category combines the two location categories in *Storm Data* of "not reported" and "at various other and unknown locations".

Open fields, ballparks, playgrounds, etc.

This is the next largest category in every region and for the US (Table 34). The same *Storm Data* categories were used by Ferrett and Ojala (1992) for Michigan to find that ball parks and playgrounds were the most frequent locations of lightning victims from 1959 to 1987.

Under trees

The third largest group in the US, and in most regions, involves people located under trees. This is a very dangerous place to take shelter when lightning is nearby. Ferrett and Ojala (1992) also found that trees were the third most frequent location for lightning fatalities in Michigan. Benjamin Franklin made the same comment over 200 years ago.

Water related, fishing, boating, swimming, etc.

In the US and most of the regions, the next highest percentage is related to the proximity of the victim to bodies of water.

Golfing; golfing under trees

It is sometimes stated that golfers are the most frequent victims of lightning. It is apparent from this analysis that golfing is not especially high on the list in most regions.

Driving tractors, farm equipment, heavy road equipment, etc.

While this category is small in *Storm Data* since 1959, agricultural activities in rural areas were one of the most common locations for lightning victims early in the century and is the subject of a study in progress by the authors.

Telephone-related

Telephones are an infrequent but persistent source of lightning casualties in all regions. The issue of telephones and lightning victims was examined in Australia by Andrews et al. (1992).

Radios, transmitters, antennas, etc.

These types of casualties occur at a low rate in all regions since antennas may be the highest objects in the immediate area.

The location categories in the digital *Storm Data* dataset are of limited use; Ferrett and Ojala (1992) are the only other researchers to use these categories. But much can be learned about the patterns and time trends in locations of lightning victims by reviewing and categorizing the information in the verbal narratives of *Storm Data*. This large task has not been performed for the US from 1959 to 1994.

Findings from research with smaller databases are difficult to intercompare since each study has its own system. The following are major features of some of this research:

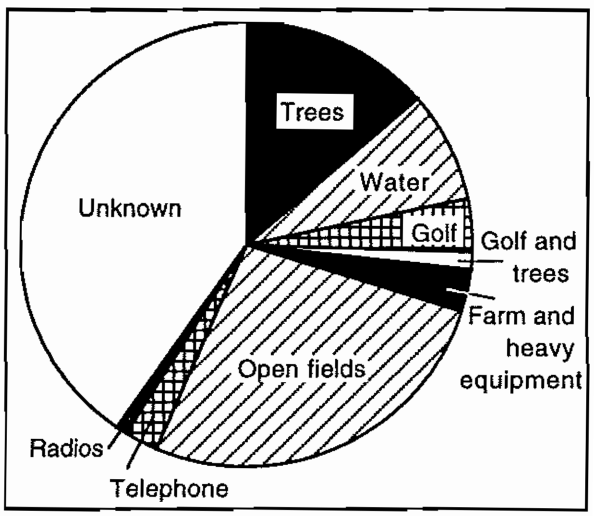

FIGURE 39. Locations of US lightning casualties from 1959 to 1994 including unknown cases.

- North Carolina medical examiner data were used to develop two different systems of locations. Lightning victims were most often at their home or in the home's surroundings from 1972 to 1984 (Duclos and Sanderson (1990). In contrast, another study found that fatalities were most often in a farm, field, or garden from 1972 to 1988 (Langley et al., 1991).
- Florida locations were summarized by Duclos et al. (1990) and Holle et al. (1992). As expected, a significant number of lightning victims were in the vicinity of water in some form.
- Lightning casualties during recreation have increased since 1950 in Colorado, while agricultural casualties have decreased (López et al. (1995).
- Outside the US, somewhat similar results were found in Singapore (Pakiam et al., 1981) and Australia (Coates et al., 1993).

It is important to go beyond the *Storm Data* digital record for another reason. Not only is location important, but the activity at the time of the lightning casualty can tell more about the lightning victim's situation. Many or most of the papers mentioned above also include or link the victim's activity to the location.

TABLE 34. Locations and numbers of lightning casualties in *Storm Data* including unknown cases (%).

Code	Location of casualty	**United States**	West coast	N Rockies	S Rockies	N plains	S plains	Mid-west	North-east	South-east
1	Under trees	**13.7%**	10.4	8.6	13.4	9.7	14.5	14.8	13.5	13.6
2	Water related, fishing, boating, swimming, etc.	**8.1**	6.1	12.5	5.5	4.0	9.6	5.3	7.4	10.4
3	Golfing	**3.9**	1.2	4.3	4.6	4.2	2.2	6.2	3.1	3.6
4	Golfing and under trees	**1.0**	0.6	0	0.3	1.8	0.4	2.1	1.1	0.8
5	Driving tractors, farm equipment, heavy road equipment, etc.	**3.0**	1.2	7.1	2.1	9.0	4.1	2.6	2.0	2.7
6	Open field, ballparks, playgrounds, etc.	**26.8**	19.0	36.5	40.5	20.6	30.4	27.1	20.6	26.2
7	Telephone-related	**2.4**	1.8	1.6	1.5	3.9	2.8	2.7	1.6	2.5
8	Radios, transmitters, antennas, etc.	**0.7**	0	2.0	0.3	0.2	0.9	0.6	0.5	1.0
0, 9	Not reported, at various other and unknown locations	**40.4**	59.5	27.5	31.7	46.7	35.2	38.6	50.2	39.2

12. DAMAGE REPORT COSTS

The most frequent cost of lightning-caused damages in the US is between $5,000 and $50,000 according to *Storm Data*. This range accounts for half of all reports between 1959 and 1994. The categories of $500-5,000 and $50,000-500,000 are also frequent. These three categories account for 92.7% of the reports. Detailed costs are shown in Figures 40 and 41, and Tables 35 to 37.

All regions of the US have the interval of $5,000-$50,000 as the most frequent amount (Table 35). The next most frequent interval is $500-$5,000. There is a tendency for somewhat higher costs from the southern plains eastward, compared to the northern plains westward (Table 35).

Decadal changes show that smaller losses have been increasing while larger amounts have been decreasing (Figure 41). Since inflation has not been taken into account, the shift is greater than shown by *Storm Data*. No obvious reason is apparent for this change.

The *Storm Data* amounts are greater than insured lightning losses in Colorado, Utah, and Wyoming (Holle et al., 1996). Those losses were paid for insurance claims by homeowners and some small businesses. Over a third of the insurance losses were between $251 and $1000, and a few were over $5000. This comparison shows that *Storm Data* tends to include more widely known events and fewer small losses. It is not possible for National Weather Service staff preparing *Storm Data* to be aware of frequent small losses when they do not result in a call to an emergency agency and are not in the newspapers.

The following details of some of the largest losses provide information on the types of expensive events that tend to reach the National Weather Service through the newspaper clipping process, and an idea of the variety of lightning damages that can occur.

<u>Over $5,000,000 (1959 to 1994)</u>

The 17 lightning losses over $5 million in *Storm Data* (Tables 36 and 37) were mainly due to forest fires; some homes were also destroyed and crops were lost. The fires were in Oregon (eight in 1987), Idaho (two in 1989), Montana (two in 1984), and Arizona (one in 1990). The other lightning losses over $5 million were from damage to a factory, an oil tanker sunk at a dock, a historic hotel, a propane truck exploded at a lumber yard, and extensive damage to a phone system.

<u>Over $500,000 (1985 to 1994)</u>

There were 92 entries over a half million dollars during these years; seven had no information. The rest can be grouped as follows:
-13 forest fires in Oregon and Idaho.
-9 home or homes.
-9 manufacturing plants.
-8 agricultural facilities.
-8 retail stores.
-7 church properties.
-7 school properties.
-7 warehouses or wholesale businesses.
-4 apartment buildings.
-4 petroleum installations.
-2 aircraft or airport facility.
-2 historic mansions.
-2 office buildings.
-One each telephone company, power substation, and building under construction.

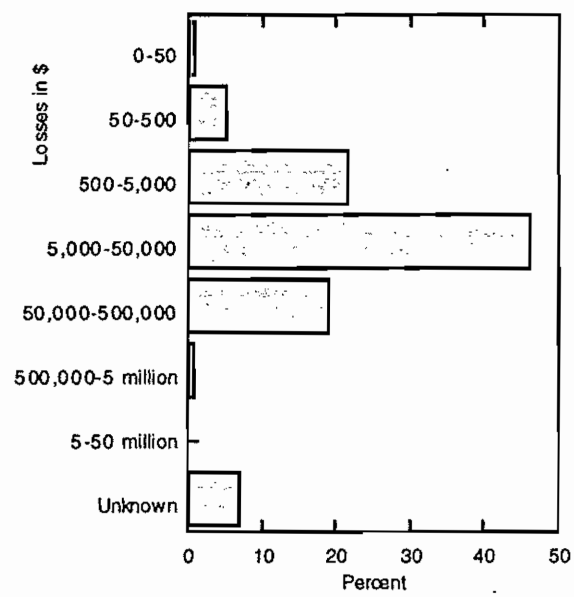

FIGURE 40. Number of lightning damage reports by year from 1959 to 1994 in the US.

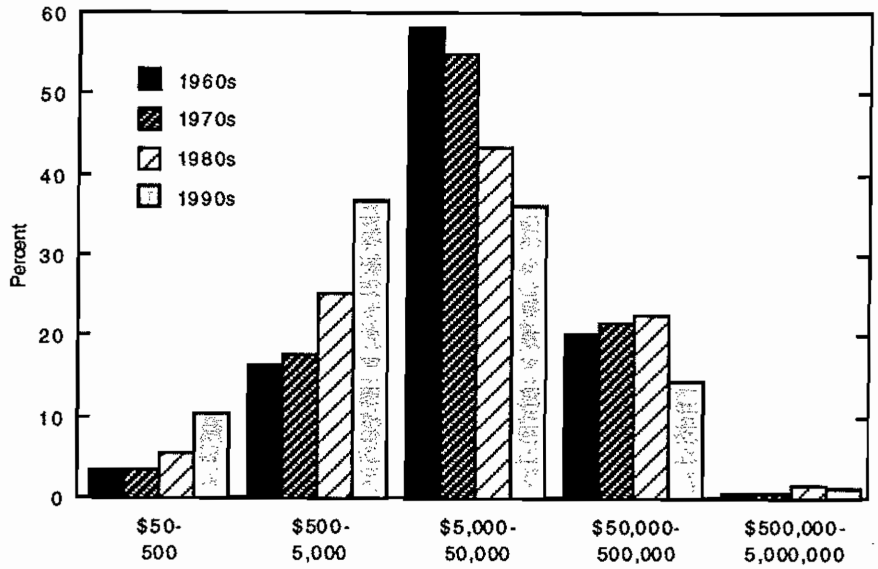

FIGURE 41. Decadal changes in US lightning damage reports for the five most frequent cost categories.

TABLE 36. Costs of US lightning damage in *Storm Data* from 1959-1994, including unknowns.

Damage Category	Incidents	% of total
$ 0 - 50	143	0.7
50 - 500	1017	5.1
500 - 5,000	4266	21.5
5,000 - 50,000	9117	46.0
50,000 - 500,000	3727	18.8
500,000- 5,000,000	176	0.9
5,000,000-50,000,000	17	0.1
Unknown	1352	6.8

The types of property damages in central Florida from 1983 to 1990, but not the damage amounts, were summarized by Holle et al. (1992). The most frequent category was residences, including mobile homes and apartments; no other large category was found. Michigan losses over $50,000 from 1959 to 1987 were mapped by Ferrett and Ojala (1992) by county.

The digital database developed from *Storm Data* contains 106 entries for 1989 that are incorrectly coded. These amounts indicate losses of more than $500 million, and were recoded for the present study as missing.

TABLE 35. Distribution of the costs of material damage by region of the US, without unknowns.

Amount	**United States**	West coast	N Rockies	S Rockies	N plains	S plains	Mid-west	North-east	South-east
$500-5,000	**23.1**	21.5	29.2	32.4	32.2	20.5	16.0	23.6	23.5
$5,000-50,000	**49.4**	41.6	45.8	39.8	46.2	52.5	48.8	48.9	51.4
$50,000-500,000	**20.2**	20.6	14.4	12.5	13.8	20.5	28.8	21.1	17.5

TABLE 37. Costs of US lightning damage in *Storm Data* from 1959-1994, without unknowns.

Damage Category	% of total
$ 0 - 50	0.8
50 - 500	5.5
500 - 5,000	23.1
5,000 - 50,000	49.4
50,000 - 500,000	20.2
500,000- 5,000,000	1.0
5,000,000-50,000,000	0.1

13. SUMMARY AND CONCLUSIONS

Lightning-related fatality, injury, and damage reports for the United States were summarized for 36 years since 1959, based on the NOAA publication *Storm Data.* There were 3239 deaths, 9818 injuries, and 19,814 property-damage reports from lightning during this period.

Florida led the nation in the actual number of deaths and injuries. Other states with high numbers of casualties were in the south and southeast, northeast, and southwest. The largest number of damage reports came from Pennsylvania. The states of Kansas, Oklahoma, Nebraska, and South Carolina did not rank as high in casualties as damages. There were large variations among decades in casualties and damages.

When population was taken into account, Wyoming and New Mexico led the nation in death, injury, and casualty rates. New Mexico had high rates in all decades, but Wyoming's casualties were almost entirely from the 1960s and 1970s. High casualty rates tended to be in Florida, the Rocky Mountains, plains, southeast, and New England. The highest rate of damage reports was on the plains from North Dakota to Oklahoma.

Population-weighted casualties decreased until the 1990s, when the rate increased again. The damage report rate also decreased until it increased sharply in the 1990s. The number of lightning-caused casualty and damage events was less variable from year to year than other weather causes. For this reason, lightning is the most constant and widespread threat to people and property during the thunderstorm season.

All types of lightning reports in *Storm Data* reached maxima during July. Casualties reached a sharper maximum in July, while damage reports were spread more evenly through the year. Casualties and damages in northern regions of the US had narrower distributions centered on summer than southern regions.

National Lightning Detection Network data in recent years were used to estimate that one lightning casualty occurred for every 86,000 flashes in the US. A similar method results in one death for every 345,000 flashes, and an injury for every 114,000 flashes. A rate of 7.7 casualties per million people per 100 million flashes was found for the US.

Two-thirds of the casualties occurred between 1200 and 1600 LST. Casualties showed a steady increase toward a maximum at 1600 LST, followed by a somewhat quicker decrease. Damage reports lagged casualties by two to three hours. They showed a steeper increase toward a 1700 LST maximum than casualties, a gradual decline toward midnight, then a slight increase again after midnight. There were relatively frequent damage reports during the night in the plains and midwest states.

Summer casualties and damages closely resembled the annual cycle. In spring and autumn, the casualty maxima are less distinct than for summer, and damages are spread more uniformly through day and night. In winter, the afternoon peak disappeared for damage reports and was weak for casualties.

Casualties were most frequent on Sunday; the next most common day was Saturday, then Wednesday; such a result is consistent with more outdoor recreational activities on the weekend. Damage reports were most frequent on Monday, then decreased on nearly every day until reaching the lowest number on Saturday; this result could be due to newspapers that do not publish every day.

For incidents involving deaths only, 91% of the cases had one fatality, while another 8% of the events had two people killed in the same incident. For incidents involving injuries only, 68% of the cases had one injury. Males were killed by lightning 4.6 times as often as females, and were 5.3 times as likely to be injured as females.

Many of the *Storm Data* entries had unknown or unreported locations for lightning victims (40%). Outdoor recreation was the next largest category in every region and for the US. The third largest group involved people located under trees, and the fourth was related to the proximity of victims to bodies of water. Although it is sometimes thought that golfers are frequent victims of lightning, they trail the preceding groups in frequency. There were not many lightning victims involved in agricultural activities. Telephones were an infrequent but persistent source of casualties, while people in proximity to radios and antennas were the least frequent category in *Storm Data*. More studies are needed of the locations around lightning victims and what they were doing than is available in the digital *Storm Data* listing.

Half of all lightning-caused damages were between $5,000 and $50,000 according to *Storm Data*. Comparison with other datasets shows that *Storm Data* entries tend to include more widely known events and fewer small losses.

Possible future enhancements of this work include comparisons of the casualty and damage results with lightning ground-strike data collected over the US since the late 1980s. Such results can compare detected flashes with state-by-state casualties and damages on annual, diurnal, monthly, and seasonal scales. Other relationships to lightning reports and flash activity should be considered, such as per-capita income, and agricultural and recreational activity by state and season.

ACKNOWLEDGMENTS

We appreciate the careful assistance of Brian Mast of the University of Oklahoma in checking the last few years of data, and in compiling with great care many of the data lists used in this report. We also appreciate the contributions by Jim and Jennifer Vavrek, science teachers in Hammond, Indiana, for their review of drafts of this publication.

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